FEDERAL ORGANIZATION FOR TECHNOLOGICAL INNOVATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

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SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

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FEDERAL ORGANIZATION FOR TECHNOLOGICAL INNOVATION

THURSDAY, JUNE 7, 1984

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:30 a.m., in room 2325, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Present: Representatives Walgren, Mineta, MacKay, Lundine, Gregg, and Skeen.

Also present: Representatives Zschau and Ritter.

Mr. WALGREN. Today, the subcommittee begins 4 days of hearings on a number of bills that, in various degrees, call for new organizational arrangements in the Federal Government, for a stronger role in technological innovation. We hope this hearing is a contribution to the ongoing discussions on future Federal policy to encourage industrial technology and move our country in the proper direction in that area.

Our scope in these hearings is narrower than what is known as the industrial policy debate, which includes such wide-ranging issues as the need for a reconstruction bank and others. In these hearings, the central question is whether the advancement of American technology needs the active participation of the Federal Government, be it in the currently highly visible, high technology sector or the more traditional smokestack industries that much of our country relies on.

Two of the bills before us, authored respectively by George Brown and John LaFalce, propose the establishment of a new agency to be known respectively as either the National Technology Foundation or the Advanced Technology Foundation. Both bills would create or bring together programs closely related to technology development. They would also establish a number of new programs, but basically they would give a strong push to Government support for research and development aimed at fostering technology to the point where commercialization would take over.

Two other bills, one by Mr. Brown again and one by Mr. Pashayan, would instead initiate major studies of the entire question of industrial competitiveness. These proposals take the view that we are not yet ready to make the important decision in this area before a good deal of additional consensus is reached. Finally, we will be taking testimony on two legislative proposals which would target Federal support on technology for the manufacturing sector. Authored by the chairman of the Committee on Science and Technology, Mr. Fuqua, this bill on the House side would provide support for new technology development in one sector of our industry which is often said to be in the most need, and that is, of course, manufacturing. This is an area where technology is believed to have moved faster in other countries and, as a result, productivity growth has exceeded that which we have experienced in ours.

We have a number of distinguished witnesses who are scheduled to contribute their views to the record and the discussion, including a number of Members of Congress who have given a lot of thought to these questions. We really want to welcome them to the committee and to the process.

I would like to recognize Mr. Skeen for any opening comments he might like to make.

Mr. **Skeen**. Thank you, Mr. Chairman. Very briefly, because I know you want to get into these hearings, I want to express my appreciation for the work that you have done as chairman of this subcommittee and for the ongoing interest that we have had in this particular issue of technological innovation.

Further than that, I want to say, too, that Members of Congress who have appeared before this subcommittee have shown a great deal of interest and a very high level of expertise in their own right. I want to commend them and say that you folks are doing an outstanding job of trying to represent these issues legislatively. We appreciate that kind of talent being embodied in this Congress. So, congratulations on the kind of work that you are doing, and welcome to all of you here. We are delighted to have Mr. Young here from Hewlett Packard. With that, Mr. Chairman, thank you very much, and we will get on with the hearing.

Mr. **Walgren**. I appreciate that statement.

Let us also include at this point in the record an opening statement by Stan Lundine, who has maintained an interest in this area, and we will leave the record open for other opening statements that our colleagues on the committee may wish to make.

[The opening statement of Mr. Lundine follows:]

OPENING STATEMENT OF REP. STAN LUNDINE (D-NY)
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE AND TECHNOLOGY

HEARINGS ON FEDERAL ORGANIZATION FOR TECHNOLOGICAL INNOVATION
June 7, 1984

The world has changed dramatically over the last two decades. There is a new global economy and intense international competition. The transition of the United States to the modern technological era has been disappointing. Concern is growing that U.S. industrial innovation is declining with negative consequences for economic growth, productivity improvements and international trade competition. For more than a decade we have suffered from basic problems which have diminished our industrial base and eroded our international competitiveness.

We are functioning in a radically changing international environment. There are new rules and we have to learn to play better by these new rules. Our present ad-hoc policymaking stands in sharp contrast with our major trading partners who have integrated economic policies into coherent programs.

It is not that our foreign competition is inherently superior. We are not lacking in the basic research that provides the foundation for innovative technologies. Our greatest problem seems to be in the intermediate research stages of applied research and commercial application. We can see that when basic research is successfully transferred to commercial markets there is growth in productivity.

In the United States industrial innovatioan for commericial purposes is primarily a private sector activity. Accelerating the pace of applied research should be an essential part of our national industrial strategy. Our principal chance to compete lies in our ability to innovate and diffuse innovations more rapidly and efficiently than our competitors. American firms have pioneered new technology only to see its commercialization by foreign competitors. One reason for their success in applied research is their willingness to provide support for the transfer of technology to the international marketplace.

It is true that industry should, and it does, carry out applied research with technology that is close to commercialization. But there are areas about which the federal government should and must be concerned. In generic research and technological development, especially for those industries not served by the Department of Defense or the National Aeronautics and Space Administration, there is no federal involvement. This has been of great concern because of the strategic importance of this work in international competitiveness. There has been continuing disagreement over the issue that the federal government should provide leadership in the process of transferring technology from basic research to the private sector for commercialization.

The Advanced Technology Foundation and the Technology Foundation have been proposed as alternate mechanisms for filling this leadership role of planning and coordinating the technology transfer process. We are not using efficiently the technological and scientific tools that we now have. There is a need for university, industry and government cooperation in providing a calculated approach to the commercialization of our research.

The federal government must provide leadership in enunciating national goals and policies and in clearly defining the relationship of the private competitive market system to government and university generated research. We must correct these inadequacies to restore our leadership in the global productivity competition.

Mr. **Walgren**. The first witness today is John LaFalce. All of you who have followed this area know he has focused on it both in his general capacity and in his chairmanship of another committee in the Congress and has been the author of one of the most specific and widely supported bills in this area.

We really appreciate your coming before us, John. Welcome to the committee.

STATEMENT OF HON. JOHN J. LaFALCE, A U.S. REPRESENTATIVE FROM THE STATE OF NEW YORK

Mr. **LaFalce**. Thank you very much, Mr. Chairman.

First I would like to ask unanimous consent to have the entire text of my statement included in the record, and I will summarize from it.

Mr. **Walgren**. Without objection, so ordered.

Mr. **LaFalce**. I want to thank you for giving serious consideration to H.R. 4361, which was reported by the Banking Committee on April 10 by a vote of 25 to 18.

The ATF proposal was developed on the basis of hearings held over the past year by the Subcommittee on Economic Stabilization, which I had the privilege of chairing. During the course of 35 days of hearings, the subcommittee examined the reasons for the decline in competitiveness of certain U.S. industries, the nature and extent of current Government policies affecting industries, and alternative policies for improving our competitiveness in the future.

We came to the conclusion during those hearings that the development and use of new and better civilian technology is most essential to the performance of the U.S. economy, both domestically and in international markets. Technological innovation, the development of new technological products, processes, and systems makes it possible for firms to produce goods and services that are of a higher quality and at a lower cost. Technological diffusion, the widespread adoption and use of improved technologies is equally important in ensuring that the economy as a whole enjoys the benefits of low-cost higher performance technologies.

In short, unless positive actions are taken to strengthen our capacity to convert basic scientific discoveries into technological innovations and to diffuse them rapidly throughout American industry, we believe that the United States faces the possible danger of losing market after market to foreign competition.

During the hearings that my subcommittee held, many witnesses provided evidence after evidence that our international competitors, particularly the Japanese and West Germans, are spending significantly higher fractions of their GNP and government R&D budgets on research with commercial applications, and that the failure to invest adequately in applied research is indeed having a serious adverse effect on America's industrial competitive position.

Often, American firms or research centers have pioneered in new technology, only to see its commercialization captured by foreign competitors: 64K RAM and videocassette recorders are all American inventions, but we did not finance research into cost-cutting ways of producing the products, with the result that each of these products is now firmly under foreign control. Indeed, 100 percent of

VCR's, a $10-billion-a-year growth industry, are currently manufactured outside of the United States.

To be sure, the Federal Government already spends a great deal of money on research and development. About 50 percent of all R&D in this country is federally funded. There are additional tax, procurement, and antitrust policies which seek to encourage or subsidize private-sector investment in research and development. Most of the direct Government support, however, goes to defense-related programs and to basic scientific research.

I am not here to argue against funding for research in the Defense Department. I am not arguing against funding levels for the National Science Foundation or other basic science research programs. Donald Fry, the chairman of Bell & Howell, told my subcommittee that it is not so much a case of too much science but rather too little engineering.

As for military research, however, I would argue that we have skewed our priorities in recent years. In fiscal year 1980, half of the Federal R&D budget was devoted to defense. Now that figure is over 70 percent and growing. This emphasis, which more appropriately could be termed overkill, has pulled talented scientists and institutional resources away from commercial-related research and toward the development of sophisticated weapons production.

Our priorities are clear, and I think they are hurting our industrial competitiveness and future economic growth. Let me put our current priorities into a devastating context when compared with the priorities and practices of our major competitors. At a time when the Japanese, West Germans and French are spending about 10 to 15 percent of their government R&D money on projects that specifically seek to stimulate industrial and generic technologies, the U.S. Government is spending less than 1 percent of its R&D budget for such purposes.

The simple fact is that the Federal Government funding for applied research and development has been reduced by over 30 percent in real terms since the Reagan administration took office. Dr. Jordan Baruch, the former Assistant Secretary of Commerce for Science and Technology, whom I know you know very well, perhaps put it best when he testified before my subcommittee:

"This country should be more concerned about being acquired than being invaded."

Some people contend that, unlike military or basic scientific research, commercial research should be the sole responsibility of the private sector. In this regard, it is important to understand that U.S.-private sector underinvestment in applied research could well be caused by market imperfections. Most firms lack the capital to undertake large R&D projects which might lead to product revolutionizing breakthroughs. Almost all firms, regardless of size, often lack sufficient incentive to undertake even modest applied research to make cost-cutting improvements in existing products because they may be unable to capture the full fruits of their innovation. If the improved technology quickly becomes available to their competitors, then the innovating firm would gain an insufficient return to justify its R&D investment.

In general, then, private-sector firms tend to focus almost exclusively on short-term R&D, which would have an immediate payback in bottom-line profit. They understandably perhaps do not invest in generic research projects that are extremely risky and may not provide any exclusive benefits. With the international competitiveness of the economy as a whole, however, the cost savings to an entire industry that can be generated from a technological breakthrough could be critical, fully justifying the costs and risks involved in the investment.

Under these circumstances, then, I believe that this is a classic case calling for public intervention to remedy a market failure which is imposing an unacceptably crippling cost on our economy.

How can the Government respond most effectively and appropriately to the problems of underinvestment in commercial R&D. There are at least three major options: tax credits for applied research, relaxed antitrust restrictions on joint R&D ventures by industry, and direct Government funding of applied research.

The Reagan administration has approached the problems principally through the R&D tax credit and the promotion of limited partnerships created to take advantage of the credit. I am not going to oppose either of those two concepts, but I would point out the following. The Joint Committee on Taxation estimates that the tax revenues foregone because of the R&D tax credit will reach approximately $1.5 billion for fiscal year 1984 through 1985. This credit is in addition to a longstanding provision of the Tax Code that permits rapid deduction of the entire cost of certain corporate R&D activities. This provision will result in a $2.5 billion subsidy for qualifying firms in fiscal year 1984 alone.

It is clear, then, that the administration is willing to spend considerable sums of money through the Tax Code to address this problem. It is not so clear, however, that this approach is as cost effective as it should be. In testimony submitted to the Subcommittee on Economic Stabilization on this issue, Prof. Edwin Mansfield of the University of Pennsylvania concluded that the R&D tax incentive has had a very small impact on private-sector R&D expenditures. In fact, Professor Mansfield maintains that for each dollar of tax revenue lost, we are only getting about 30 cents in added R&D. Moreover, we are now starting to get the usual horror stories of how a Government program can get subverted when it is insufficiently targeted.

In yesterday morning's Washington Post, for example, there was an article on the tax credit. It cited a study by Professor Eisener of Northwestern that said we are getting less research and development on account of the tax credit. In my opinion, there is at least a very real prospect that the R&D tax credits will prove to be a great program for accountants and lawyers but might not generate very much actual increase in R&D. So I think we should be extremely cautious about that and certainly not make it permanent within the Tax Code without much further study.

A second alternative is for the Federal Government to relax antitrust restrictions on joint research and development ventures by firms in an industry. This would certainly be a useful tool to encourage R&D efforts that individual firms might be unwilling to undertake but which a consortium of firms might be able to afford. I think that approach has merit, but while it has merit it also has inherent limitations which we should realize.

Not all industries are active in research and development, and many would not undertake joint ventures even if permitted to do so. In addition, highly concentrated industries are in a better position to benefit from such ventures since firms in such industries already have significant R&D investments. Further, there is a possible danger of anticompetitive results from such ventures. Where the research moves from generic to product-specific technology, we have to be careful of that.

For these reasons, we should be careful as we move to change our antitrust laws by carefully delineating any relaxation of antitrust constraints on cooperative R&D so that we can be sure that what we are allowing is in fact a more efficient pooling of funds and talent at the industry level.

A third and, in my view, the best alternative—although these are not exclusive—for promoting increased investment in applied research and disseminating the results would be direct Government funding of applied R&D projects. I believe this approach makes the most sense for several reasons. First, direct funding assures that every Government research dollar goes for research and not for some other purpose. Second, direct funding allows Government support for research to be guided to the most promising projects. It is a blanket entitlement program, like the tax credit, which supports every research project regardless of its merit. Third, direct funding allows us to hold accountable the recipients of Federal support and evaluate the outcome of the Federal expenditure. Fourth, since the Federal Government directly shares in the research investment, it can seek to ensure that the fruits of the research are widely disseminated to the benefit of the entire economy. Fifth, a program of direct funding would foster the development of better economy-wide networks of communication and an atmosphere of cooperation among industries, universities, and Government agencies at all levels. In sum, direct funding is the approach that, in my view, assures the greatest return for the Government research dollar. Again, I do not think it should be the only approach we take; I certainly think it is a definite approach, and I think it is the best approach.

For those who view most Government programs with suspicion, programs of this nature such as the Advanced Technology Foundation that I advocate and the National Technology Foundation which Congressman Brown advocates, I would point to the history of accomplishment of the National Science Foundation, the NIH, NASA, and other Government-funded research programs such as those within the Department of Agriculture.

The new era of international competition makes it incumbent upon us now to consider the merits of a direct funding approach, whether it be the Advanced Technology Foundation that I have suggested or some other approach. I think there is a strong case, too, for a separate institution. I am aware that it has been argued often that increased spending for applied technology could most easily be implemented through the National Science Foundation. I do not think that would be a very good idea.

The NSF has a broad-enough mandate and serves a large-enough constituency as it is. As several witnesses testified before my subcommittee, we must constantly keep in mind that science and technology, while definitely related, are distinct activities independent of one another. They are closely linked in many ways, but the development of new technologies is a fundamentally different activity from scientific research. Science and technology have different objectives. Most importantly, they have different constituencies. In my judgment, they should also have different agencies to encourage their efforts.

I am also aware of the suggestion that implementation of the Stevenson-Wydler Technology Innovation Act of 1980 would eliminate the need for the Advanced Technology Foundation. I would respond that it is precisely because such measures as Stevenson-Wydler are within the larger bureaucracy of the Commerce Department that the need for such a separate institution is underscored. Stevenson-Wydler has not been properly funded or given much visibility, and the Commerce Department appears at this time to be wholly inadequate to the task of pursuing such responsibilities in a serious, vigorous and consistent manner.

H.R. 4361 would locate the responsibility for technological development in a separate mission-oriented agency that will be supported by its own constituency and judged on its own merits.

In conclusion, Mr. Chairman, the Advanced Technology Foundation proposal which you have before you today, in my judgment is a prudent and cost-effective mechanism for stimulating the kind of applied research which our economy needs to maintain our international competitiveness. The level of funding proposed for this agency is very modest, considering the need. Indeed, if fully appropriated, this program would constitute about 1½ percent of the research budget of the Federal Government but would more than double the amount of Federal resources now directed at this problem. Additionally, the proposed funding level for the Advanced Technology Foundation would be only a fraction of the revenue losses that the Treasury has sustained through the open-ended R&D tax credit program which has produced insufficient results.

Finally, I again want to thank the members of this subcommittee for the opportunity to discuss H.R. 4361 today and other bills. I particularly want to emphasize that the members of the Banking Committee wish to cooperate, indeed, to defer to the much greater expertise of the Science and Technology Committee as to how the concerns and issues outlined in my statement can be best addressed.

We are most aware of the budget squeeze, the existing research programs within the jurisdiction of this committee, and the pressures that such budgetary constraints impose when considering the establishment of any new agency at this time. For our part, we simply want to work with this subcommittee and this committee in any way possible to promote technological innovation in this country. So I urge the subcommittee to give the issues being discussed serious and speedy consideration, and whatever your subcommittee or committee decides to do, I want you to know that you can call upon the Banking Committee to help in your efforts. Thank you very much.

[The prepared statement of Mr. LaFalce follows:]

Mr. WALGREN. Thank you very much, Mr. LaFalce.

Let me invite Ed Zschau, who has just come in the room, to join us and come on up.

CONGRESSMAN JOHN J. LAFALCE
Testimony on H.R. 4361
before the
House Subcommittee on Science, Research and Technology
June 7, 1984

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Good morning. I would like to thank you, Mr. Chairman, and the Members of this Subcommittee for giving serious consideration to H.R. 4361, a proposal to establish an Advanced Technology Foundation ("ATF") which was reported by the Banking Committee on April 10 by a vote of 25 - 18.

As you know, the ATF proposal was developed on the basis of hearings held over the past year by the Subcommittee on Economic Stabilization, which I chair. During the course of 35 days of hearings, the Subcommittee examined the reasons for the declining competitiveness of U.S. industries, the nature and extent of current govenrment policies affecting industries, and alternative policies for improving our competitiveness in the future.

We came to the conclusion during those hearings that the development and use of new and better civilian technology is essential to the performance of the U.S. economy, both domestically and in international markets. Technological innovation--the development of new technological products, processes and systems--makes it possible for firms to produce goods and services that are of higher quality and at a lower cost. Technological diffusion--the widespread adoption and use of improved technologies---is equally important in ensuring that the economy as a whole, enjoys the benefits of lower-cost, higher-performance technologies.

In short, unless positive actions are taken to strengthen our capacity to convert basic scientific discoveries into technological innovations, and to diffuse them rapidly throughout American industry, we believe that the United States faces the very real prospect of losing market after market to foreign competition.

THE NEED FOR H.R. 4361

Today, our country is locked in a critical competitive struggle which will determine the kind of economic future our country will have. It is a struggle for market share, for jobs, and for economic leadership in the international economy. In the aftermath of World War II, the United States dominated the international economy with virtually effortless superiority; but this historic dominance has been sharply eroded in recent years as other nations entered the international marketplace as serious, vigorous, competitors.

In this increasingly intense struggle, we will be able to maintain our standard of living only by constantly innovating new products and production processes.

There is disturbing evidence, however, that our industries as a whole--"high tech" and "smokestack" alike--are failing to meet the challenge of competitive innovation. While American scientists continue to lead the world in the production of new knowledge, American industry too often trails behind the rest of the world in applying those new discoveries to the process of economic production. Americans continue to sweep Nobel Prize awards every year for scientific advances, yet our trade imbalances grow larger and larger. This peculiar pattern, in which we invent and they innovate, will eventually mean that the center of gravity in the world economy will shift to those countries which are doing a better job at commercial innovation.

H.R. 4361 is designed to help bridge the gap between basic research and the commercialization of new products or processes, through federal support for generic and cost-cutting technological research and through the creation of an industrial extension service to speed up widespread adoption of innovations throughout the national economy.

UNDERINVESTMENT IN APPLIED RESEARCH

At the very time when it is becoming increasingly important to the United States to be more innovative, our economy is simply not making the investments necessary to stimulate and support technological innovations. A technologically stagnant American industry will inevitably be overtaken by foreign producers able to take advantage of cheaper labor and the widespread availability of existing productive technology.

During the hearings held by the Subcommittee on Economic Stabilization, many witnesses provided evidence that our international competitors (particularly the Japanese and West Germans) are spending significantly higher fractions of their GNP and government R&D budgets on research with commercial applications; and that the failure to invest adequately in applied research is indeed having a serious adverse effect on America's industrial competitive position.

Because of insufficient attention to new product development, American industry has been increasingly overtaken in international markets by foreign firms using innovative products--basic oxygen steel furnaces, for example. In many other cases, American firms or research centers have pioneeered a new technology, only to see its commercialization captured by foreign competitors. The 64K RAM, the videocassette recorder, and the MAGLEV rail system are all American inventions, but we did not finance research into the cost-cutting ways of producing the products, with the result that each of these "products" is now firmly under foreign control. Indeed, 100 percent of VCR's--a $10 billion a year growth industry--are currently manufactured outside of the United States.

To be sure, the Federal Government already spends a great deal of money on research and development--about 50 percent of all R&D in this country is federally funded--and there are additional tax, procurement, and anti-trust policies which seek to encourage or subsidize private sector investment in research and development. Most of the direct government support, however, goes to defense-related programs, and basic scientific research.

I am not here to argue against funding levels for the National Science Foundation or other basic science research programs. As Donald Frey, Chairman of Bell and Howell, told my Subcommittee, "It is not so much a case of too much science, but rather too little engineering."

As for military research, however, I am prepared to argue that we have skewered our priorities in recent years. In FY 1980, half of the federal R&D budget was devoted to defense--now that figure is over 70 percent, and growing. This emphasis--which could more appropriately termed overkill--has pulled talented scientists, and institutional resources away from commercial-related research and toward the development of sophisticated weapons production. Our priorities are clear, and they are badly hurting our industrial competitiveness, and future economic growth.

Let me put our current priorities into a devastating context when compared with the priorities and practices of our major competitors: At at time when the Japanese, West Germans, and French are spending about 10 to 15 percent of their government R&D money on projects that specifically seek to stimulate industrial and generic technologies, the U.S. Government is spending less than 1 percent of its R&D budget for such purposes. The simple fact is that Federal Government funding for applied research and development has been reduced by over 30 percent in real terms since the Reagan Administration took office. Dr. Jordan Baruch, former Assistant Secretary of Commerce for Science and Technology, perhaps put it best when he testified before my Subcommittee that "...this country should be more concerned about being acquired than being invaded."

Some people contend that unlike military or basic scientific research, commercial research should be the sole responsibility of the private sector. In this regard, it is important to understand that U.S. private sector underinvestment in applied research is caused by a classic case of market imperfection. Most firms lack the capital to undertake large R&D projects which might lead to product-revolutionizing breakthroughs. Almost all firms, regardless of size, often lack sufficient incentive to undertake even modest applied research to make cost-cutting improvements in existing products, because they may be unable to capture the full fruits of their innovation. If the improved technology quickly becomes available to their competitors, then the innovating firm would gain an insufficient return to justify its R&D investment.

In general, then, private sector firms tend to focus almost exclusively on short-term R&D which will have an immediate payback in bottom-line profits. They simply, and understandably, do not invest, in generic research projects that are extremely risky and may not provide any exclusive benefits. For the international competitiveness of the economy as a whole, however, the cost savings to an entire industry that can be generated from a technological breakthrough could be critical, fully justifying the the costs and risks involved in the investment. Under these circumstances, then, I believe that this is a classic case calling for public intervention to remedy a market failure which is imposing an unacceptable crippling cost on our economy.

DIRECT FUNDING--THE MOST EFFECTIVE RESPONSE

How can the government respond most effectively and appropriately to the problems of underinvestment in commercial R&D? There appear to be three major options: tax credits for applied research; relaxed antitrust restrictions on joint R&D ventures by industry; and direct government funding of applied research.

The Reagan Administration has approached the problems principally through the R&D tax credit, and promotion of limited partnerships created to take advantage of the credit. The Joint Committee on Taxation estimates that the tax revenues foregone because of the R&D tax credit will reach approximately $1.5 billion for FY 1984-1985. This credit is in addition to a long-standing provision of the Tax Code that permits rapid deduction of the entire costs of certain corporate R&D activities. This provision will result in a $2.5 billion subsidy for qualifying firms in FY 1984 alone.

It is clear, then, that the Administration is willing to spend considerable sums of money through the Tax Code to address this problem. It is not so clear, however, if the Administration's approach is cost-effective.

In testimony submitted to the Subcommittee on Economic Stabilization on this issue, Professor Edwin Mansfield of the University of Pennsylvania, concluded that the R&D tax incentive has had a very small impact on private sector R&D expenditures. In fact, Professor Mansfield maintains that for each dollar of tax revenue lost, we are only getting about 30 cents in added R&D. Moreover, we are now starting to get the usual horror stories of how a Government program can get subverted when it is insufficiently targetted. In my opinion, there is a very real prospect that the R&D tax credits will prove to be a great program for accountants and lawyers, but will generate very little actual increase in R&D.

A second alternative is for the Federal Government to relax antitrust restrictions on joint research and development ventures by firms in an industry. This would certainly be a useful tool to encourage R&D efforts that individual firms might be unwilling to undertake, but which a consortium of firms might be able to afford. While this approach has merit, it is important to recognize its inherent limitations. Not all industries are active in research and development, and many would not undertake joint ventures, even if permitted to do so. In addition, highly concentrated industries are in a better position to benefit from such ventures since firms in such industries already have significant R&D investments. Further, there is a danger of anticompetitive results from such ventures where the research moves from generic to product-specific technology. For all these reasons, a blanket removal of antitrust strictures on joint research efforts would not be wise, and certainly would not be a panacea for our inadequate investment in applied research. However, a carefully delineated relaxation of antitrust constraints on cooperative R&D might allow more efficient pooling of funds and talent at the industry level.

A third, and in my view the best, alternative for promoting increased investment in applied research and disseminating the results is direct government funding of applied R&D projects. I believe this approach makes the most sense for several reasons. First, direct funding assures that every government research dollar goes for research and not some other purpose. Second, direct funding allows government support for research to be guided to the most promising projects. It is not a blanket entitlement program like the tax credit which suports every research project regardless of its merit. Third, direct funding allows us to hold accountable the recipients of federal support, and evaluate the outcome of the federal expenditure. Fourth, since the federal government directly shares in the research investment, it can seek to assure that the fruits of the research are widely disseminated to the benefit of the entire economy. Fifth, a program of direct funding would foster the development of better economy-wide networks of communication and an atmosphere of cooperation among industries, universities and government agencies at all levels. In sum, direct funding is the approach that, in my view, assures the greatest return for the government research dollar.

For those who view most government programs with suspicion, I would point to the history of accomplishment of the NSF, NIH, NASA, and other government-funded research programs such as those within the Department of Agriculture. The new era of international competition makes it incumbent upon us now to consider the merits of an Advanced Technology Foundation.

THE CASE FOR A SEPARATE INSTITUTION

Unless, and until, we recognize that technology has become a principal determinant of international competition, the U.S. economy will be unalbe to effectively compete with those countries that have explicitly acknowledged its importance. Our economic competitors have, without exception, agencies whose principal mission is the promotion of civilian technology. We have decided to make such efforts "step children" within agencies whose primary purposes and focus are elsewhere. The results have been predictably disappointing. Given the importance of technological innovation to our economy, it is time that we establish an independent agency with the resources to do the job, and the separate constituency to make sure that its programs cannot be held as a pawn in some larger political, bureaucratic, or ideological debate.

I am aware that it has been often argued that increased spending for applied technology could be most easily implemented through the National Science Foundation (NSF). I do not think that this is a good idea. The NSF has a broad enough mandate and serves a large enough constituency as it is. As several witnesses testified before the Subcommittee on Economic Stabilization, we must constantly keep in mind that science and technology are distinct activities, independent of one another. Although they are closely linked in many ways, the development of new technologies is a fundamentally different activity from scientific research. Science and technology have different objectives, and different constituencies. They should also have different agencies to encourage their efforts.

I am also aware of the suggestion that implementation of the Stevenson-Wydler Technology Innovation Act of 1980 would eliminate the need for the Advanced Technology Foundation. I respond that it is precisely because such measures as Stevenson-Wydler have not been implemented within the larger bureaucracy of the Commerce Department that the need for such an a separate institution is underscored. Stevenson-Wydler has not been properly funded, or given much visibility, and the Commerce Department appears, at this time, to be wholly inadequate to the task of pursuing such responsibilities in a serious, vigorous and consistent manner. H.R. 4361 would locate the reponsibility for technological development in a separate, mission-oriented agency that will be supported by its own constituency, and judged on its merits.

CONCLUSION

In my opinion, the Advanced Technology Foundation proposal which you have before you today is a prudent and cost-effective mechanism for stimulating the kind of applied research which our economy needs to maintain our international competitiveness. The level of funding proposed for this agency is very modest, considering the need. Indeed, if fully appropriated, this program would constitute about 1 1/2 percent of the research budget of the Federal Government, but would more than double the amount of federal resources now directed at this problem. Additionally, the proposed funding level for the Advanced Technology Foundation would be only a fraction of the revenue losses that the Treasury has sustained through the open-ended R&D tax credit program which has produced insufficient results.

While it is possible for reasonable people to disagree on the specifics of a solution to the problem of inadequate applied research, there should be no serious debate on the urgency of the problem. If all of us, private firms, universities, scientists and the government fail to rise to the competitive challenge in the area of applied research, the result is predictable -- stagnation in our standard of living as we watch other nations capture our markets and the imagination of our own consumers. None of us want such an outcome, and none of us need experience it if we recognize that we must act now to improve our nation's ability to innovate and compete.

Finally, I want to again thank members of this Committee for the opportunity to discuss this legislation today. H.R. 4361, and other bills, being considered before this Subcommittee today are positive ways to move forward on this issue. In this regard, I particularly want to emphasize that Members of the Banking Committee wish to cooperate--in fact, defer--to the much greater expertise of the Science and Technology Committee as to how the concerns and issues outlined in my statement can be best addressed.

We are aware of the budget squeeze on existing research programs within the jurisdiction of this Committee, and the pressures that such budgetary constraints impose when considering the establishment of any new agency at this time. For our part, we simply want to work with this Subcommittee and Committee in any way possible to promote technological innovation in this country.

I urge this Committee to give the issues being discussed today serious and speedy consideration, and whatever the Committee decides to do, I want you to know that you can call upon the Banking Committee to help in your efforts.

We certainly appreciate that testimony. It is such a sound presentation. I find such frustration, coming from a part of the country that is similar to your part of the country, in the lack of economic recovery that we have had and the lack of encouraging prospects for basic smokestack manufacturing industries. Certainly, something cries out to be done.

How did you set your $500-million-level in this process? Can you give any assessment of what the reach of that level of effort would be?

Mr. LaFalce. Basically, we doubled the existing commitment, and we tried to spread this out. But certainly those figures are most negotiable. From our understanding of the budget constraints, I think we would probably need considerably more. When you look at the money that is being spent through the Tax Code now and the payoff that we are getting, I think this would be most modest indeed in comparison. I think that the cost-benefit relationship that we get would be far greater through direct funding than through the Tax Code approach.

Mr. Walgren. In the Tax Code approach, what is the rationale for the conclusion that we are not getting very much "bang for the buck" there? Is it that this research would have been done anyway? How are they making the judgment that we are only getting 30 cents on the dollar.

Mr. LaFalce. I would refer you to the full study of Professor Mansfield of the University of Pennsylvania, Professors Eisener of Northwestern, and so on. I think Professor Mansfield did his study for the National Science Foundation. As to the methodology, I think in part it is because of their judgment that this research would have been done anyway, in part because they say that maybe it is not really research and development. It is being called research and development, in part because of the provisions of the Tax Code which says that you can only get the tax credit for certain incremental types of research, too, and this might have diminishing returns after a while and be a disincentive for research. Each individual who has argued has come up with different reasons for his argument.

I am not against this. Understand what I am saying. But I do not think that we should make it a permanent provision of our Tax Code. I think we should examine what we have been able to buy with our tax expenditures thus far much more carefully before we make it permanent, and I think we ought to realize that the approach it takes is a very general approach. To a certain extent, we are just tossing dollars out.

Maybe our system to advance the entrepreneurial process, if you will, has to be part of our overall approach. It is a general approach. I also think, though, we need not just a general approach; we need a specific approach. Mr. Zschau and I have gotten into many debates, and he has frequently said we have to target the entrepreneurial process not specific industries. My rejoinder has always been, yes, we must target the entrepreneurial process. So I do not oppose what you are advocating; I, too, have advocated those things. But I also think we have to target specific industries, especially if those specific industries are being targeted.

Within the context of research and development, I think we have to foster an atmosphere where research and development can prosper. Perhaps the limited use of our Tax Code is a way of doing that, but I also think we have to go from the general to the specific, and we have to foster specific research projects, too. I think we are not doing that right now. If it is being done, it is not being done adequately. It is being done through the Defense Department. It is not being done through Stevenson-Wydler. It is not being done through the National Science Foundation, insofar as the type of research and development I am talking about. That is primarily basic.

I think we need a complementary approach.

Mr. WALGREN. I would like to recognize my colleagues for thoughts they might like to raise. Mr. Mineta.

Mr. LAFALCE. I want to emphasize again, too, that I am going to defer to the much greater expertise of this subcommittee and full committee that have been dealing with science and technology matters since you have been sitting on it. We are relatively new to this area, but these are our best judgments on the basis of the evidence that we have heard. It is very limited in comparison to what you have heard.

Mr. MINETA. John, let me ask you, in the work that you have done, has there been a way to quantify the benefits that come from direct-expenditure programs as compared to tax-expenditure programs?

Mr. LAFALCE. I think the National Science Foundation has attempted to do that in order to justify their programs. I think they have concluded that there is a much higher return.

Mr. MINETA. Is it not a problem that in terms of a direct categorical program for assistance, R&D, innovation or whatever might be referred to, that first of all you have to have an agency doing that, and second, you are in effect going through that whole argument about having to pick winners and losers. Should we be doing that?

Mr. LAFALCE. Does not the National Science Foundation pick winners and losers every day? Does not the National Institute of Health pick winners and losers? Does not the NASA pick winners and losers? Does not the Defense Advanced Research Project Agency [DARPA], within the Department of Defense, pick winners and losers? The difficulty with the Tax Code is, it does not make any attempt to pick winners and losers. It says: Everybody will have the money, no matter how meritorious; If you do this type of activity, we are not going to be discriminating.

What I am saying is, we need a blend of both approaches. We need the general, and we need the specific. We really do not have the specific. This subcommittee must have made the judgment, when they advocated passage of the Stevenson-Wydler Act on a very bipartisan basis, that you needed the specific approach. The problem with Stevenson-Wydler is that it simply has not been funded. It hasn't been funded, in large part I think, because it is simply one of many responsibilities of the Department of Commerce, and there has been no visibility to it.

Insofar as the need for this, too, I think the chairman said that maybe we need some greater study. I would point out that the Office of Technology Assessment has made a study of the need for such an institution. They did it at our request. It is a rather exhaustive study, and they said clearly, we need such an institution. I would refer you to the study of OTA on this issue. I would clarify that this is a staff study; it has not been adopted in toto by the official board, but the staff study is quite explicit and quite definitive.

Mr. **Mineta**. What would be the difference between your ATF approach versus the proper funding of the Stevenson-Wydler Act?

Mr. **LaFalce**. You could probably do it either way. I just think that you are going to be able to develop the program much better, develop a constituency for it, give it much greater visibility. You are going to be able to enhance its effectiveness much better through this approach. If this subcommittee makes the judgment, we have to get funding of Stevenson-Wydler and let's put all our eggs in that basket, I will support the approach of this subcommittee. I think we would have a better chance of accomplishing our goal, of being successful, if we try to create a new agency, independent, and very mission oriented, similar to the way we created the National Science Foundation.

If we just passed a law giving the Department of Commerce the responsibilities that the National Science Foundation has, I think it would get lost in the overall responsibilities of the Department of Commerce. It has too many responsibilities. I think the National Science Foundation has this one responsibility for science, and I think we ought to have one agency with this one responsibility for technology.

Mr. **Mineta**. Just to digress a bit, when I was on the budget committee chairing the budget process task force, I wanted to include in the budget resolution a portion outlining all of the tax expenditure programs, the revenues that we were losing through tax expenditure approaches, just to make visible how much we were losing in revenues as compared to how much we were spending in direct programs that already show in a budget resolution.

As we try to get a handle on direct spending, everyone gets more and more innovative and says, "Let's go the tax credit route instead." I have no problem with tax credits. I think we also have to have that as a visible item in terms of how much dollars as compared to direct expenditures.

Mr. **LaFalce**. There is a bias on the part of the private sector toward utilization of the Tax Code. They almost have an anti-Government bias. Because of the anti-Government bias, if you go to the Tax Code, you don't have to deal with Government. Also, too, you can spend that money for almost anything you want. Again, I think we need an appropriate balance between tax incentives and direct funding.

Mr. **Mineta**. Thank you, John, for your leadership.

Thank you, Mr. Chairman.

Mr. **Walgren**. Mr. Gregg.

Mr. **LaFalce**. Mr. Gregg, more than anybody, knows how little I know about technological and scientific matters because we suffered through a computer course together.

Mr. **Gregg**. Obviously, philosophically, there is an inconsistency with my basic belief, which is that you let the marketplace settle this issue.

Mr. LaFalce. If you favored Stevenson-Wydler, if you favor the National Science Foundation, if you favor NASA and NIH, if you favor DARPA, I do not think we have any inconsistency at all.

Mr. Gregg. Yes, you do, because the National Science Foundation, for example, or the Department of Energy are committed to basic research. In the times when they get out of the basic research business and get into the applied research area, or even get into the commercialization areas, they have been abysmal failures.

I would take, for example, the National Science Foundation's experience with solar-heated dog houses and the whole applied process that they went through, where they sought grants for the commercialization activities as a failure.

The question I guess is: How can we as a government, functioning here in Washington, even if we set up a separate entity which is science-oriented, how can we possibly make that what I consider to be massive leap from institutionalized structure to that individualized initiative that creates movement in science or in commercialization, that entrepreneurial spirit? How can we ever, as a government and simply by the constraints put on a government, expect that we are going to be able to pick out and choose what is going to drive an entrepreneurial spirit?

Mr. LaFalce. How is DARPA doing it today? How is DARPA making the decision to advance the fifth-generation computer?

Mr. Gregg. That is different, because you are talking about specific events. If you want to be specific, and if you want to say, "All right, in these areas we are going to commercialize. We are going to move the Federal Government into commercialization," then we have a debate on each one of these areas. We come to the conclusion that in the national interest, we have to commercialize the supercomputer, or we have to commercialize in the high-tech area, in the long-term-energy area of fusion. We have to pay for that step. Or breeder technology, which I do not happen to agree with, but we made that decision at one point.

Fine. We make those decisions on massive Federal action in very targeted areas, however, those areas are defined primarily by the fact that they are long-term high-risk areas. For us as a government to just set up a great big pool of money and say, "Come and get it" to the commercial sector, we are never going to—I think what you are going to find is, you are going to have just a whole series of solar dog houses out there being funded by people at the Federal level.

Mr. LaFalce. I am curious as to what the difference then, other than the institutional difference, would be between Stevenson-Wydler's approach and an Advanced Technology Foundation or the National Technology Foundation advocated by Chairman Brown? Stevenson-Wydler, as I understand it, would provide moneys for the commercialization of our scientific discoveries for technological development and advancement, only it has not been funded. It is my understanding that this committee thought that was, on a bipartisan basis, the most necessary and wise approach.

Mr. Gregg. I cannot speak to that because I was not here at the time, so I am just addressing your bill right now. I would suspect that, since it has not been funded, that probably answers the question: the decision was made that it is not going to work.

Mr. **LaFalce**. The Reagan Administration has spoken of Stephenson-Wydler as if it is a wonderful law, as if it has achieved marvelous results. The fact of the matter is, I think that is more rhetoric than anything else. They have not spoken about the basic concept of it.

Mr. **Gregg**. I am not speaking for the Administration; I am speaking for myself. My concept is that the Federal Government, when it starts getting into the business of commercialization, is going to be a failure because institutionally it is incapable of discriminating between what is going to work and not work in the private sector. Public sector activity cannot do it. But I would be happy to yield to somebody else.

Mr. **Walgren**. In deference to the time constraints of our next witness, I think I ought to recognize the gentleman from New York for some brief thoughts, and then we ought to get on to Mr. Young who has a time limit with us this morning.

Mr. **Lundine**. I appreciate the chairman's quiet way of underscoring the word "brief." I would just ask unanimous consent to put the opening statement that I prepared into the record following any opening statements by the ranking minority member.

Mr. **Walgren**. Without objection, that has been so ordered.

Mr. **Lundine**. First of all, I would just like to compliment my colleague and friend. I have been in the Congress for 8 years. I will admit that I have a bias on the issue or a point of view on industrial competitiveness, but I have never been privileged to participate in hearings as comprehensive, as thorough, or as interesting as the ones that he chaired on the Economic Stabilization Subcommittee. I really think that he has done the Nation a service by just bringing out all the different points of view. I do not think those hearings were any attempt to squelch any particular point of view.

You got into this a little bit. How do you answer the charge that what you are going to do is allow bureaucrats to choose promising or effective technology, when in fact the marketplace is the only instrument to make that choice?

Mr. **LaFalce**. I suppose whenever the Government is involved, you can always bring up the word bureaucrat and you can always bring up the concept of winners and losers. I think we just have to understand that if Government has to be involved, you have to deal with an individual who works for the Government; and if Government is going to make the decision, you can always call that Government decision "picking winners and losers." That seems to me to be a rhetorical device which can be used in a specific circumstance, but it can be used generally against any Government involvement in any activity whatsoever. You can always talk about a bureaucrat because you are always talking about a Government official. You can always talk about picking winners and losers whenever Government has to make a decision.

So you would have to argue against dealing with the Government, and you would have to argue against the Government making decisions. How can you structure this? Well, this is up for grabs as to how you can structure it. But certainly, you know how much I favor the concept of consensus. It would seem to me that one of the first things you would do would be to get together the private sector, and within the private sector you would have to say, "What do we really need? What would you like to do if you had the money to do it?" Then you are going to have to make some judgments.

There is going to be disagreement within the industries. There is going to be disagreement within the private sector. The National Science Foundation has a number of advisory panels that assist them in their effort. So I do not have any hard and fast approach that should be used, but certainly I would want tremendous input from the private sector as to what is needed.

Mr. **Lundine**. Recognizing the time constraints, I would just like to follow up briefly. The National Science Foundation, as you know, has a system of peer review. Are you suggesting a sort of an industrial peer review process?

Mr. **LaFalce**. Absolutely.

Mr. **Lundine**. Thank you.

Mr. **LaFalce**. That is not without its own difficulties, to be sure, but we must make decisions somehow and I think that is probably the best approach to make decisions.

Mr. **Ritter**. I appreciate all the work that the gentleman from New York has done on this subject. I would just like to point out that his proposal for this supergroup of peers to review is perceived very differently by different segments of the society. There is a segment that perceives this industrial policy allocation process as capable of helping those that are in dire need of help to somehow overcome their shortcomings.

Mr. **LaFalce**. You are talking about H.R. 4360, I believe, Don, and this is H.R. 4361. I really would like to limit it to H.R. 4361, and maybe we could debate H.R. 4360 at another time.

Mr. **Ritter**. What is the difference between H.R. 4361 and H.R. 4360?

Mr. **LaFalce**. H.R. 4360 would establish a Council on Industrial Competitiveness. H.R. 4361, which I am discussing today, would create an Advanced Technology Foundation. I think you are talking about the bill that you considered in the Energy and Commerce Committee. That is not the bill that we are considering today.

Mr. **Ritter**. Please excuse my misunderstanding of 1 digit out of 4,360 bills.

Mr. **Walgren**. We could submit some outline of the reservations that might be had about this bill for the record, if you want.

Mr. **Ritter**. I have somewhat different concerns about this one, but I think at this point I would like to defer to the chairman and get on with the schedule.

Mr. **Walgren**. I appreciate the understanding of the members that they are extending the Chair at this point. I want to underscore Mr. Lundine's respect for the work that you have done in this area, particularly the hearings and the record that has flowed from them, and express our appreciation and respect for your involvement in this area.

Mr. **LaFalce**. Thank you. And I want to underscore my realization that the members of this subcommittee have far greater knowledge and expertise in this area than do I or, generally speaking, the members of my subcommittee and committee and our wish to defer to you and to cooperate with you as you make your deliberations and judgments.

Mr. WALGREN. Thank you very much.

At this time, I would like to recognize Mr. Mineta. One of the great virtues of the Congress is that we come from all sectors of the country. Therefore, we often have members who are intensely involved with areas of the country where private citizens who are making significant contributions are constituents and are in our immediate areas. Coming from the peninsula area of San Francisco, that is the case with this next witness, and I would like to recognize Mr. Mineta for his introduction.

Mr. MINETA. Thank you very much, Mr. Chairman. It is clear from the range of bills presently under consideration by this subcommittee that there are a myriad of approaches the Government might use in encouraging and supporting technological development in the United States. To proceed, however, we must have some clear understanding of how industries presently in the forefront of technological development and marketing envision Government cooperation in their areas of expertise.

Hewlett-Packard is a company located in Mr. Zschau's district, in our area known as Silicon Valley, and since shortly after its modest beginnings has been recognized as a leader in the very creative and competitive world of high technology. The president of Hewlett-Packard and its chief executive officer is Mr. John Young, a gentleman of considerable experience, not only in industry itself but also in the Air Force Research and Development Command and currently as chairman of the President's Commission on Industrial Competitiveness. We are, therefore, especially fortunate in having Mr. Young appear before this subcommittee today to share with us many of his own thoughts on the issues before us and to set forth some of the conclusions and thoughts put forth by the Commission which he now chairs.

He is a graduate of Oregon State University, and just as the person who chairs this subcommittee I believe has his Ph.D. from Stanford University, and our colleage, Mr. Zschau, has his Ph.D. also from Stanford University, our witness next has his MBA from Stanford University. In contrast, I am a Berkeley graduate. Although Mr. Young is the vice president of the board of trustees of Stanford University, and notwithstanding Mr. Young's credentials, I am just pleased to fill the room with as many Californians as possible. So I would like to welcome Mr. Young, Mr. Chairman.

Mr. LUNDINE. At the risk of taking all of the time for introductions, I wonder if Mr. Zschau would like to say anything.

Mr. ZSCHAU. I would just like to welcome the witness, my good friend, John Young. One thing I might add is that the Hewlett-Packard Co. is regarded around the world as one of the best-managed companies, not just in the electronics industry but in all industries. It is a real tribute not only to the founders of the company but its current chief executive officer, John Young.

Mr. LUNDINE. From a different part of the country and probably a different perspective, I would like to say that I viewed the President's Commission on Industrial Competitiveness with a great deal of skepticism, maybe one might even say cynicism, particularly because it was originally due to give its report within two months of the 1984 elections. From what I can tell of what is going on, I am pleasantly surprised. It is not the first time I have been wrong, but

I am really delighted, Mr. Young, with your work in that regard and also, I might say, delighted that you have persuaded somebody to delay the report because I think it enhances its credibility because of the elections to delay it until sometime later this year. We really do welcome you and appreciate your appearing here.

STATEMENT OF JOHN A. YOUNG, CHAIRMAN, PRESIDENT'S COMMISSION ON INDUSTRIAL COMPETITIVENESS, AND PRESIDENT AND CEO, HEWLETT-PACKARD CORP., PALO ALTO, CA

Mr. YOUNG. Thank you very much, Mr. Lundine. I have very much looked forward to appearing before this subcommittee, and I have submitted my remarks in advance.

Mr. LUNDINE. Your entire testimony will be made a part of the record.

Mr. YOUNG. Thank you, and I will just synopsize a few things from that in the interest of time and then respond to any questions any of you have.

I believe the subcommittee has picked an important area of inquiry. Our competitiveness, in my view, can no longer be taken for granted even by many of the areas which we regard as the leading edge of our competitive strength. Like the electronics area for example. It is interesting to observe that last year the bilateral trade deficit between the United States and Japan in electronics was a negative $8 billion, only a few billion short of the Carter trade deficit. So I do not think we can be too sanguine about our abilities to do everything we can to facilitate the competitiveness of our country and our leading technology industries.

The technology area is certainly important to our country. Product technology has allowed us to have unique and advanced products that have real value in the marketplace. Process technologies have created proprietary methods for manufacturing things at low cost historically, and these things combined to provide the higher standard of living that our Nation's citizens enjoy. I think very clearly at stake is the ability to continue that higher standard of living, and that means continuing to earn that kind of return in order to justify that standard.

These kinds of ideas are very much along the lines of the President's charter to the Commission on Industrial Competitiveness. We are not only looking at the competitive nature of the technology base industries but also the use of technology in a wide variety of the more basic industrial sectors in order to improve the competitiveness of that activity. This Commission was established by the President in June 1983, and as you indicated, Mr. Lundine, we are to complete our work by December 1984.

There are 30 commissioners, including a wide variety of academic leaders, business leaders, the President's science adviser, union members, and so forth. I appreciate your complimentary remarks; the Commission is hard at work, and we are indeed broadly studying this question and certainly we respect Congressman LaFalce's work in this area as well.

I would like to take a couple of minutes to outline some of the broader commission work and give you a feel of the complexity of the competitiveness issue. While we also concluded that technology is kind of a centerpiece of much of what we are talking about, it is indeed a complicated issue, an interrelated issue of competitiveness. One could excel at technology and still lose. For example, it is clear from the testimony we have taken, one of the few times that a whole series of economists have agreed on anything that I am aware of, they unanimously feel that the cost of capital in the United States is between 1½ and 4 times greater than that of one of our leading trading partners, Japan.

So, having the best technology still is not enough to necessarily ensure competitiveness, and that is why I would continue to underscore your interest in and understanding of a whole set of related issues. It is not possible to drive things ahead on a single point, but rather one needs to look broadly at these issues and make sure that a set of complementary policies come about. Government is frequently criticized for having conflicting goals and directions with respect to these issues.

Our own Commission's work is organized into four committees. One is human resources, including skills, attitudes, and costs for resources. We are looking at capital resource questions, as I indicated, various alternatives with respect to outside areas like the savings rate, tax policy, but also internal cash flow generation mechanisms. We are looking at questions of international trade, a myriad of ways in which international practices either serve to limit our access to markets or to prejudice American firms' competitiveness, and in what ways we can effectively promote exports and respond to unfair practices. Of course, one of the most important areas we are looking at is research and development and manufacturing technologies, and the role of technology in promoting competitiveness.

We have found some very strong interest in these areas. For the Administration, we work with Secretary Baldrige and the Cabinet Council on Commerce and Trade. We have been encouraged by the Administration's people to bring forward recommendations as they occur. That is a little bit of a different approach for a commission which often goes off and then brings back a final report. We are trying to have an interaction on an on-going basis, and I think this has been quite helpful in keeping us directed and beginning to form an interaction with a broader set of people, including this Commission.

We have already made some recommendations concerning research and development issues, incentives to invest, protection of intellectual property, antitrust barriers, and this sort of thing. We have a continuing agenda in the research and development area, having to do with innovation of commercial products; what we can do to strengthen this area, somewhat along the lines of the discussion just preceding. We have asked Bill Miller, president of Stanford's SRI International, to lead a small ad hoc group looking specifically at this question. We have been looking at the manufacturing technology issue. It is rather interesting to find that only two universities we can identify have any kind of a graduate-level research and faculty training program in manufacturing research. In fact, IBM's $50 million grant to accelerate the development of this area has been a very pivotal one, really galvanizing things into action, providing the resources to move this important area ahead.

We are looking at questions about getting more value from the U.S. national laboratories, founded at about $15 billion a year, and we are looking at partnership relationships, including leapfrog technologies in steel as at least one possibility of getting additional value and coupling on this basic research investment.

I would like to just say a word or two about Hewlett-Packard Co., about our own organization and some observations on the research and development effort. We will spend $600 million in our company this year on R&D. It is the third largest private electronic research and development program in the United States. We have almost half of our business outside the United States, and we are the 13th largest exporter in dollar terms in the United States. So we are a very important earner of foreign currency for the United States.

Year in and year out, we find that research and development drives our whole business, and that in any year, one-half of our orders will come from products introduced in the preceding 3 years. So, organizing to retain the entrepreneurial spirit as we grow to 80,000 employees, and to continue to facilitate this flow of products and associated processes is really at the heart of what we do.

Our research and development director, who has just retired, had a wonderful saying. He said that the difference between theory and practice is that practice takes into account all of the theory. I could not help thinking about that saying as I was hearing Representative LaFalce discuss how the R&D tax credit really does not have any effect, since in our own company, spending $600 million, we actually raised our spending by 1 full percentage point of sales during this period. So, again, I refer to the difference between theory and practice—and you can take this datum point for what it is worth.

So the question is, what can we do? What could the public sector do to facilitate things from the frame of reference of the Hewlett-Packard Co. Frankly, I do not think I can comment on the six bills that you have before you. They are quite a complex array. But rather, I backed up and thought that maybe there were some cardinal points—I called them "facts" in the testimony—that have some associated criteria about them that might serve as benchmarks. They represent some points of view of mine that I think are mostly subscribed to by members of the President's Commission that ought to be benchmarks used in evaluating legislation.

Fact No. 1: I think it is difficult to predict which technologies are going to be successful in the marketplace. Time after time we find that even skilled judgments of companies involved are incorrect. One of the stories I think that catches the flavor of this is one Bob Noyce, who was the cofounder of Intel and the inventor of the microprocessor, likes to tell on himself. He recites the story about his wife, Ann, who asked his advice about making an investment in a small company. After thoroughly reviewing the issue, Bob recommended that she not make this investment because he was pretty sure that the field they were in was not too promising. After all, how many people could possibly be interested in having a personal computer. Of course, the company turned out to be Apple; it is now a billion dollars a year company. His wife works for Apple, as a matter of fact; and Apple is one of the largest customers for Intel's circuits. So you see, even those with a very good view of the technology and related business areas find that this is really the central part of making business judgments.

We think that the closer to the market you are, the better you are going to do that, but it is extremely hard to be very good, even when you are very close. We quite agree with the theory that Ed Zschau espouses—that is, target the process of innovation, build up the capability, fill the bowl fuller so that more and more people can benefit from this and draw on additional resources and put them to work using their own insights and knowledge of the marketplace to make that happen.

Fact No. 2: The marketplace is continuously changing. Proposals should provide for feedback from the marketplace. Public policy development should be coupled to the market through some kind of mechanism, such as shared funding or ways of aligning the purposes of the market with the funders. Again, I could not help but respond to Representative LaFalce's response to a question about going out to ask industry what they would like to have happen and what they would like to fund. That is fine; you can do that, but at the same time, you ought to ask them if this is so important, why aren't you doing it already. What is it that you are doing instead of this?

The list you are going to get is the list that just fell off of their own set of priorities. Guaranteed. That is the last one they did not fund. So it gives you some benchmark about where it falls in their hierarchy of things they probably want to do.

Fact No. 3: Capacity to fund research depends on our ability to reap rewards from that research investment over time so the resulting products of innovation can be sold in world markets. Therefore, successful technology products must be competitive in two fundamental ways, in both cost and quality. The Japanese have shown that technology can be imported—most of their's is—but the careful attention to manufacturing, both in cost and quality, really has tremendous competitive characteristics in itself. So manufacturing technology must be given serious investigation, and the requirements must be considered very much as part of the research charter. We must very much address the quality and cost issue.

So innovations and process technology can help minimize the disadvantage of high-cost human resources. In fact, that is the principal way in which we must gain the productivity that can retain the standard of living differences that we enjoy.

Fact No. 4: Technology is dynamic and mobile. It goes to industrializing nations, such as Korea, which just 20 years ago was in a great shambles, already has state-of-the-art technology that is very comparable to the best in the world and is rapidly getting into the semiconductor business. So these proposals must recognize that the time available to firms for development is shrinking, the mobility of technology is growing around the world, and developing countries are finding new strategies to cut across old developmental ideas of using low-cost labor in making textiles, for example. Rather, they are catapulting to the front of the technology area as basis for development.

Fact No. 5: There are limited Federal funds to support R&D generally, and no other organization is likely to fund significant amounts of basic research. This is the fundamental role of government. So other kinds of proposals to help in applied research should not divert existing Federal fundings of the basic research program. Federal assistance should not displace already-planned private-sector research either. That would be, again, a useless application of Federal money.

Fact No. 6: We think research done on university campuses provides the dual benefits of advancing basic knowledge and providing critical training for engineers and scientists. A great deal of the basic work in the country is done by the leading research universities, and we think proposed policies should probably explore the possibilities for using universities as the vehicle for research programs.

Dave Packard has completed a study as part of the President's private-sector studies on cost control, in which he believes that more effective management of the Federal laboratories might result in savings of $6 to $9 billion. If that indeed were the case, and if that money could be redeployed to, let's say, the universities, you would literally double the level of university research support from the Federal Government.

These are directions to review. Of course, building the faculty structure up and the supporting equipment and facilities is absolutely critical. I am sure this committee is well aware of a serious faculty appointment situation. Between 10 and 20 percent of the faculty appointments in key engineering disciplines are unfilled today. U.S. youngsters are not choosing graduate study for the Ph.D. as a field nor going into the faculty profession. George Low, president of Rensselaer Polytechnic and a member of our commission, has documented this subject quite well, and I attach his paper to my testimony.

So we think that the criteria mentioned here are consistent with the lessons we have learned from our own experience at Hewlett-Packard, as well as the observations that one can draw from past government activities, and I hope you find them useful in your considerations of legislation before you. With that, I am happy to respond to questions.

[The prepared statement of Mr. Young follows:]

PREPARED STATEMENT
HOUSE SUBCOMMITTEE ON SCIENCE AND TECHNOLOGY
BY
JOHN A. YOUNG, CHAIRMAN
PRESIDENT'S COMMISSION ON INDUSTRIAL COMPETITIVENESS
JUNE 7, 1984

Thank you for the opportunity to address the Subcommittee on the question of Federal and private support for technology development and industrial innovation.

I believe this Subcommittee has chosen an important area of inquiry -- an area which plays a key role in the future of U.S. competitiveness. The competitiveness of American industry can no longer be taken for granted. Despite the current upturn in the economy, we are troubled by long-term trends affecting our ability to compete in world markets. As evidence, let me cite the fact that even the electronics industry -- which is often noted as one of the strongest growth sectors of our economy -- suffered a $8 billion trade deficit with Japan last year. That's almost as large a bilateral trade deficit as the U.S. automobile industry. So the deliberations of this Subcommittee are very welcome.

The focus of this hearing is both timely and appropriate. Technology always has contributed significantly to America's high standard of living and it has done so in two ways. First, we have incorporated technology into our products, making them so unique that we could charge a premium price for them. Secondly, we have applied technology to the manufacture of our products, increasing our productivity to the point where our products could be cost competitive, even with a workforce which earns a higher wage than many workers elsewhere. I believe both product and process technology are strongly linked to our nation's standard of living. Therefore, the continued maintenance of our national well-being calls for increased efforts to maintain our technological edge.

The President's Commission on Industrial Competitiveness

The subject of this hearing also is very consistent with the charge of the President's Commission on Industrial Competitiveness. One of the Commission's prime areas of interest is technology -- both the competitiveness of America's technology-based industries, as well as the use of technology as a competitive tool in a wide variety of industrial sectors. Our charge from President Reagan is to review means of increasing the long-term competitiveness of U.S. industries at home and abroad, and we are to recommend to the President policy changes at all levels of government to improve the private sector's ability to compete.

Established by President Reagan in June 1983, we are scheduled to end our work by December 31 of this year. The Commission consists of 30 members from industry, universities, and unions with governmental representation by Dr. George Keyworth, Science Advisor to the President. Our members are distinguished leaders in their respective fields and represent a diversity of viewpoints. They are ideally suited to contribute to a national dialogue on the kinds of actions required by the public and private sectors to make U.S. industries more competitive.

In response to our assignment, we are submitting individual action recommendations to the Cabinet Council on Commerce and Trade as consensus is reached. We also are working on a framework which will articulate an overall strategy for U.S. competitiveness. Both will be incorporated into our final report which will be submitted to the President when the Commission completes its work. Through this approach, we hope to produce a long-term, action-oriented plan which can play a useful, positive role long after the Commission ceases to exist.

The action recommendations mentioned above are being developed and put before the full Commission for approval by its four committees, each charted to cover a critical competitiveness policy area. These four areas are: human resources, capital resources, international trade, and R&D and manufacturing. The overall framework to help integrate these separate policy areas is being developed by a fifth committee headed by Dr. Michael Porter of Harvard University. The initial work of this committee focused upon identifying competitive factors that hold the most promise for ensuring an American advantage. The entire Commission is in consensus with its conclusion that technology is where the U.S. has a great opportunity to leverage its strengths.

Issue Areas Under Study by the Commission

I would like to take a few minutes to discuss the issues being addressed by each of our four committees. This will give you a feel for the complexity of the competitiveness problem and the fact that there are many factors affecting our ability to compete in technology markets. Indeed, those issues could overwhelm our technological excellence.

For example, a critical factor determining economic success of U.S. firms is the state and stability of the U.S. economy. Inflation, high interest rates, and uncertainties about future economic conditions could mitigate the benefits of other policies to help industrial competitiveness. Therefore, attention by all policy makers should be given to ensuring stable and viable economic growth. Other proposals should be reviewed for their contribution to this goal.

Returning to the Commission's work, our human resources committee is examining the skills and attitudes our workforce will require, as well as ways we can minimize the competitive disadvantage posed by the high cost of the American workforce. We recognize that America's high standard of living has to be earned: that the marketplace doesn't bestow it upon us as a right. Earning that standard of living will require us to improve productivity, and that again points to your emphasis on technology -- especially process technology.

Second, our capital resources committee is examining the role of capital as part of our ability to compete. We are certain that the high cost of capital in the U.S. relative to Japan puts us at a real disadvantage. We can cite the Japanese success in the U.S. semiconductor market as an example where high capital costs have put American manufacturers at a strong disadvantage in a field where we originally were, and in the same respect still are, technologically dominant.

Third, our international trade committee is exploring the complexities of the international marketplace and the myriad of ways international practices limit access by American firms to technology markets. This committee also is investigating ways the U.S. can more effectively promote exports and respond to unfair foreign trade practices in a more timely manner.

Our last committee, R&D and manufacturing, is reviewing the role of technology in providing a competitive edge for American industry, and I'll be returning shortly to some of its -- as well as the other committees' -- conclusions so far.

We have found a strong interest in these difficult issues by Cabinet members -- Secretary Malcolm Baldrige in particular -- as well as the White House and key Members of Congress from both political parties. This interest is significant because of the promise it gives for implementing our recommendations.

The Commission's Recommendations and Concerns

I will now take a few minutes to tell you about the recommendations we've made so far. The Commission has approved a total of 14 recommendations -- six in the area of R&D and manufacturing, four concerning international trade and the remainder in the area of human resources. Among them:

-- Concerning R&D, we would enhance the incentives to invest in this area through permanent tax credits for R&D, strengthened protection of intellectual property, and reduction of antitrust barriers to organizing joint R&D.

-- Concerning international trade, we have called for competitiveness to be a consideration in renewal of the Export Administration Act, recommended the establishment of a government data bank on foreign markets and competition to encourage small business export, called for enactment of the Foreign Sales Corporation Act, and recommended improved U.S. trade law practices.

-- In the area of human resources, we have recommended steps to improve the quality of education, both for college level engineering personnel and more general high school science and math capabilities. In addition, we have endorsed the principle of labor-management cooperation and called for new collaborative efforts in this area.

-- In regard to capital resources, active investigation also is underway concerning the high cost of capital faced by U.S. firms versus that faced by Japanese firms.

More specific to your interests, we are also pursuing the following questions:

-- Since the U.S. appears less effective in the part of the innovation process that develops research results into commercial products, are there new public policies or private actions that could strengthen this important area? We have recently initiated a special study of this question with the help of outside experts.

-- What can be done about the relative lack of U.S. progress and performance in the manufacturing technologies? Moving from design to effective production seems to take much longer in the U.S. than in Japan and often results in higher costs and lower productivity.

-- Since the U.S. National Labs possess many highly talented engineers and scientists and the Federal government spends about half of the nation's total R&D, can partnership relationships be established in conjunction with existing research programs to help develop technology needed to make major U.S. mature industries competitive? As a test the Commission's R&D committee is exploring the feasibility of an approach to help the steel industry define and exploit new ways to make steel. Discussions between industry and government representatives thus far are very encouraging.

A Private Sector View of the Technology/Innovation Process

The underlying process we are all trying to stimulate is technological innovation. Since this process is critical to the future of technology driven companies such as Hewlett-Packard, it may help to share with you a view from the private sector.

My pleasure in addressing you today stems not only from my role as Chairman of the President's Commission on Industrial Competitiveness. I am also President and Chief Executive Officer of Hewlett-Packard Company. Here in the U.S. we employ almost 60,000 people in the design and manufacture of electronic instruments and computers. Almost half of our business is international, and we are the thirteenth largest exporter in the U.S. Hewlett-Packard is the nation's third largest private electronics research organization, and we believe that our past growth and success have stemmed from our ability to innovate and bring the fruits of our research to market. Our research labs provide a constant stream of new products, and last year fully two-thirds of our sales came from products that were less than three years old. Innovation has fueled our growth, and that is another reason I am very interested in the subjects addressed by this committee.

Let me mention some of the keys to success based on the Hewlett-Packard experience. I don't assume that they all can or should be applied to other organizational settings. This is what has worked well for us. I hope, however, there may be some lessons here that apply elsewhere:

— Establish a clear objective that strategically positions the organization to be entrepreneural.

— Foster an R&D ethic in the organization and make innovation synonymous with the future of the firm. At Hewlett-Packard, the product becomes a cultural value -- the subject of every chat -- and the way to make a valued contribution to the company. The psychic rewards go to the innovators and innovation becomes a "superordinate" goal for the company.

— Provide freedom of action by giving people an opportunity to innovate and control resources.

-- Organize in small groups to allow employees to see the impact of their contributions. Large organizations are not by definition harmful to innovation; however, size must be managed effectively. Hewlett-Packard has 51 operating divisions with an average of 1,000 people in each to achieve this objective.

-- Concentrate on non-financial incentives. Surprisingly, we do not find that money is a primary motivator to spur innovation. It can, however, be a significant disincentive if pay levels are low. Money, in our experience, is not an important psychic reward.

-- Diversify research programs. We have research labs at Hewlett-Packard with charters that differ in significant ways. One group of labs is attached directly to our manufacturing operations and emphasizes leading edge engineering and manufacturing technologies, while our central lab focuses on basic developments in science and engineering in areas of interest to us. That is not to say that the divisional labs haven't developed breakthrough technologies for us or that the central labs aren't interested in linking science to the marketplace. The central labs at Hewlett-Packard are our venture capital equivalent -- putting science to work in creative new ways. The corporate labs, by contrast, focus on applying science to the solution of practical problems.

-- Ensure flexibility. To be innovative, an organization -- even a relatively successful innovator such as Hewlett-Packard -- can never, and I emphasize the word, rest on its laurels. Just because an organizational structure or problem-solving approach worked well one year does not mean it is appropriate the next year. Our research laboratory charters are left flexible because we cannot tell what the end results will be when one of our scientists or engineers begins pursuing an idea. We want to avoid what I consider a true tragedy where a good idea is thwarted by a bureaucratic wall.

Through the areas mentioned above, I have illustrated the private sector's important role in the innovation process. Now, I will turn to the public sector's role in this area. While some action has been taken in the last two years by the Administration and Congress to enhance U.S. technology and innovative excellence via increased funding, there are several areas which still need your attention or action.

What the Public Sector Could Do

The six bills on which you focus these hearings include a large and wide ranging number of proposals. I would like to reserve my own observations on the specifics until the Commission has had an opportunity to take positions on these pieces of legislation. However, I will try to be helpful by identifying several criteria which I believe are valid for judging the feasibility and worth of action proposals in the areas we are discussing. In each case, I will preceed the criteria by my perceptions of the facts of industrial life that help explain why these criteria are valid.

Fact 1: It is extremely difficult to predict which technologies and applications of technology will find acceptance in the market. Bob Noyce, who is the inventor of the microprocessor that serves as the basis for much of modern computing, tells a story on himself that illustrates this point. Some years ago, Bob's wife came to him and said she wanted to invest in a small start-up company. Bob advised her against it, saying that this new invention called a personal computer wouldn't go far. Today, that small start-up is a billion dollar company, Apple Computer, and personal computing has indeed gone far.

If participants in a market find it difficult to prejudge the commercial potential of a technology, then people further removed from the market -- members of government -- are going to find accurate prediction even more unlikely.

> Criteria: If government wants to augment research capabilities, it should provide support for a wide range of technologies. As Congressman Ed Zschau so accurately states, we should target the process of innovation, rather than try to pre-select which specific technologies will be successful. Further, governmental members should not be solely responsible for choosing which areas of research have commercial promise. The private sector is, by definition, more closely tied to the market, and members from the private sector should play an integral role in guiding the directions for federally funded research intended to help competitiveness.

Fact 2: The marketplace is constantly changing.

> Criteria: Proposals should provide for feedback from the market to research programs. R&D programs should be coupled to market needs and responses through real time relationships. Among the ways to do this are shared funding by industry in Federal applied R&D activity, participation by industry in planning Federal R&D programs, and increased support for competitive assessment information.

Fact 3: The capacity to fund research -- whether in the private or public sectors -- depends on our ability to reap rewards from that risk investment. The resulting products of innovation must be sold in world markets. To be successful, a technology product must be competitive in two fundamental ways -- cost and quality. Those two elements are the basis of any buying decision.

A corollary fact: The Japanese success in technology markets has been due to their application of technology -- much of it imported -- to the manufacture of products that are superior in cost and quality. It does America little good to create innovative technologies if, within a very short time, our products can be replicated and produced elsewhere with better quality and price.

> Criteria: Manufacturing technology must be given serious investigation. Proposals with eventual commercial objectives must include mechanisms to build competitive cost and quality into the program and policy. In any design, process technology must be given equal weight to product technology. Manufacturing requirements and competitive production processes must be considered as part of the

research charter. Innovations in process technology will enable us to increase productivity and minimize the disadvantage posed by the high relative cost of our human resources.

Fact 4: Technology is both dynamic and mobile. Industrializing nations such as Korea have access to state-of-the-art technology from both the U.S. and Japan and can rapidly turn that technology into marketable products. A technology transfer process that formerly took years now takes only months or weeks. The rate of development of new technology also is increasing and the lifecycle of products is being reduced.

Criteria: Proposals must recognize the time available to firms for development is shrinking. Your proposals must address this issue and develop mechanisms to minimize time delays built into any program in order to meet the government's fiduciary responsibility to the taxpayer. In other words, the red tape traditionally required for governmental accountability must be minimized if your purpose is to help U.S. industry restore its competitiveness.

Fact 5: There are limited Federal funds to support R&D generally and no other organization is likely to support significant amounts of basic research.

Criteria: Proposals to help applied research should be carefully structured so as not to divert existing Federal funding for basic research. We should not risk the nation's long-range future to help solve a short-range problem. For similar reasons, any Federal direct assistance in conducting or funding R&D should not displace existing or planned private sector R&D.

Fact 6: Research done on university campuses, whether basic or applied, provides dual benefits -- advancing the country's scientific knowledge base and providing critical training for the next generation of engineers and scientists.

Criteria: Proposed policies and programs should explore possibilities for using universities as the vehicles for research programs. Since Federal money is in particularly short supply these days, Congress and the Administration might take a hard look at the recommendations on National Labs prepared by Dave Packard as part of the President's Private Sector Survey on Cost Control. This report estimated that effective management of our entire Federal research budget could realize a savings of $4.5 to $9 billion per year. We should consider pursuing the changes suggested and direct those savings to augment research in our universities and other non-profit institutions. The minimum possible savings cited -- $4.5 billion -- represents the total of Federal funding to university research last year.

Adequate training of engineers also plays an important role in the long-range improvement of U.S. manufacturing. One of the members of our Commission, Dr. George Low, President of Rensselaer Polytechnic Institute, prepared a special paper on engineering education. I have attached it to this statement and commend it to your attention.

Conclusion

I think the criteria I have mentioned are consistent with most current industrial thinking on what actions are likely to stimulate innovation. I hope these criteria are useful to you to test the many proposals you are considering. Thank you for the opportunity to share these ideas with you.

Attachment

President's Commission on
Industrial Competitiveness
6/4/84

ENGINEERING EDUCATION

ISSUE

During the past several years, intense concern has been expressed over the state of our engineering education system, and how it ultimately affects the quality of the goods we produce, and the productivity of American industry.

There is a direct relationship between engineering education and industrial competitiveness. To compete we must produce goods that perform better, are priced lower, and have a higher quality than others that are available in the world market. To do this we need an ever expanding base of knowledge in science and engineering as a result of research; and the engineering talent that can develop superb designs as well as world class manufacturing techniques and processes.

The fundamental question is whether our engineering education system is producing the people and research results that industry needs now and in the future.

BACKGROUND AND ANALYSIS

This question is best addressed by considering four separate issues:

1. Engineering Graduates
    - a) numbers at bachelor's, master's, doctor's levels
    - b) mix among various disciplines
    - c) substance and content of education
2. Engineering Faculty
    - a) shortage
    - b) understanding of engineering practice
3. Engineering Research
    - a) level of support
    - b) specific areas being supported
4. Engineering Equipment
    - a) in undergraduate teaching laboratories
    - b) for graduate education and research.

1. Engineering Graduates

To begin the discussion of the numbers of engineers graduating in the United States, the following table is presented:

	1972	1982
Enrollment, Full Time Undergraduate	195,000	404,000
Enrollment, Full Time Graduate	36,000	51,000
Degrees Granted, Bachelor's	44,000	67,000
Degrees Granted, Master's	17,400	18,500
Degrees Granted, Doctor's	3,800	2,900

These figures suggest that the undergraduate pipeline has filled rapidly in response to the current demand. However, shortages still exist in selected fields (e.g., electronics, computers). In those areas, the demand of the marketplace is alleviating the problem somewhat--the number of bachelor's degrees granted in computer engineering was 7.5 times greater in 1982 than in 1972, while there has been a substantial decrease in the number of entering chemical engineering freshmen in rapid response to the declining job market.

The problem of mix among disciplines will be alleviated further as engineers in all disciplines will have a better knowledge and understanding about computers and electronics, and the demand for specialists in these fields will decrease.

The same is not true at the graduate level. The ratio of master's to bachelor's degrees has decreased from 0.39 to 0.28; and at the doctor's level the absolute number of degrees granted has declined by 25%--a number that does not tell the whole story because the number of United States citizens among graduate students has declined much more rapidly than the total.

Based on these data (as well as more detailed data for the intervening years and by engineering curriculum), one can reach the conclusions that:

a) The shortage of engineers with bachelor's degrees is improving, but in specific areas, shortages continue;

b) The mix among the various curricula will take care of itself, but somewhat slowly;

c) There does not appear to be any adjustment in numbers at the graduate level (master's and doctor's), so that the existing shortages at these levels may well continue.

But what about the substance of what is being taught in our engineering schools today? For a period of time starting at the end of World War II, there was a tendency in our engineering schools to shift away from engineering practice and toward engineering science. This shift coincided with the availability of large sums of Federal funds for basic engineering research and a simultaneous reduction in university-industry relationships. Thus, the best of our faculty, and therefore the best of our students, became far more interested in the science underlying engineering than in working on practical applications of the scientific results. At the same time more fundamental knowledge needed to be taught, and one by one the practical hands-on engineering courses and experiences gave way to theory. Moreover, the typical entering engineering student now comes with less practical experience than those of earlier periods. For all of these reasons, the distinction between scientist and engineer has become blurred. Much has been written to suggest that the recent decline in American quality and productivity is related, at least in part, to the decline in engineering practice at our colleges and universities as just described.

Many engineering schools have started to reverse this trend to bring renewed balance to the educational process. Some have invested heavily in the modern equivalent of the drafting table—the computer and the computer graphics screen; others have started efforts in manufacturing engineering, quality control, and the application of microelectronics. Several have turned once again to industry, not only for the funding available from industry, but especially to get the involvement and close relationship with the end user of engineering graduates and engineering research--the American manufacturing company.

All of these moves are in the right direction. However, there is a view held among many that the numbers of engineers produced who have both the essential fundamental understanding of physical and engineering principles, and the practical bent required of the working engineer are still very small.

The need for engineers with a practical bent exists not only at the bachelor's level, but at the graduate level as well. In fact, there is so much material to be covered even by the journeyman engineer that before too long the master's degree could and perhaps should replace the bachelor's degree. The demand for engineers with doctorates to go into industry is also increasing as a result of the complexity of much computer-based machinery and, of course, engineers with doctorates will continue to be in demand by industrial and government research laboratories as well as the universities.

In summary:

a) The shortage and mix of engineering graduates at the bachelor's level are taking care of themselves.

b) The shortage at the master's and doctor's levels is continuing.

c) There is a need, at all levels, to provide renewed emphasis to produce engineers who can contribute as practical engineering professionals.

2. Engineering Faculty

The shortage of engineering faculty continues. The best estimates indicate that there are 1400 vacancies out of a total of 18000 engineering faculty in the United States (1982 data). This number has been fairly constant over the past several years, and stems from the larger engineering enrollments, the declining number of Ph.D. graduates, and the need for faculty to devote increasing amounts of time to research.

Another reason for the current faculty shortage is the fact that the engineering laboratories at our universities are generally much less well equipped than those in industry. As a result, many researchers believe that they cannot make the most significant contributions while on university faculties, and therefore choose a career in industry. This clearly has an effect, both on the quantity and the quality of engineering faculties.

Starting salaries for engineering faculty have become quite competitive with industrial salaries in recent years. On a 12-month equivalent basis these salaries now range between $40,000 and $45,000 for fresh Ph.D.'s, slightly higher than those paid in industry. Thus the faculty shortage is not directly related to starting salaries, but there may be an indirect relationship, based once again on the stipends paid to graduate students, on the overall economic payback of the Ph.D. (whether at the university or in industry), and on the esteem (or lack of esteem) in which faculty positions are held.

Faculty members at most institutions are encouraged to consult with industry, and at some institutions to have industrial ties with the work that they do on campus. In addition, at most institutions, there are some faculty members who have recent full-time experience in industry. Thus, there exists a basic understanding among many faculty members of engineering practice in industry today. Just how this is passed on to the students depends a great deal on the kind of work in which faculty members and their students are currently involved. If that work is engineering science-oriented, then that is what students will learn; if it is related to engineering practice, then the students will also be immersed in the practical aspect of engineering.

The involvement of engineering faculty in cutting edge research, as well as their close interactions with industry, also has a profound benefit to undergraduate education: Teachers who participate actively in what is going on in the world will make their lectures much more interesting and exciting, and will motivate their students accordingly.

An important issue for faculty to address, on a continuing basis, is how quickly to change the curriculum in response to changing discipline requirements and technologies used in industry. The matter of balance between an education that stresses the fundamentals, and one that stresses current applications is of key importance. The American education system, with its emphasis on fundamentals, has in the main produced engineers who are able to shift in a rapidly changing technological environment. Yet much of the thrust of this paper leads in a direction toward a more practical orientation. It is therefore essential to guard against the pendulum swinging too far in that direction.

An involved faculty, with experience in industry and at the cutting edge of research, should help assure such a balance. Additional involvement by industry, on advisory councils, and through the ranks of adjunct faculty should also bring greater realism to university research and teaching.

In summary:

a) There continues to be a shortage of engineering faculty.

b) Many engineering faculty members are quite capable of involving students in the practical aspects of engineering.

3. Engineering Research

Traditionally in this country most of the basic and some of the applied engineering research has been conducted in our universities, and has been supported by the Federal government. Although there has been a recent trend toward more support by American industry, it is not expected that this support will reach more than about 20% of the total.

Much of the government support has been in the areas of engineering sciences rather than engineering practice. Equally important, the level of engineering support has not taken into account the fact that most research today is becoming "big research;" and that much of it can no longer be done by individual investigators, but must be done by teams of investigators.

There is also a question concerning the specific directions of research that should be pursued. In many fields of science (e.g., chemistry, physics, astronomy), there have been comprehensive studies sponsored by the National Science Foundation (and undertaken by the National Research Council of the National Academies) to help establish the direction for future research and, hence, National Science Foundation funding. The same has not been true in engineering. However, there is currently underway the beginning of a National Research Council (NRC) study to establish the need for engineering research, and to help set the directions for that research. This study should have an initial output in time for the fiscal year 1986 budget decisions.

In the meantime, there has been one specific study (after a comprehensive review of a number of fields of engineering) on the use of computers in design and manufacturing. This study was undertaken by the Academies' Committee on Science, Engineering, and Public Policy (COSEPUP), and led to a "research briefing" for the President's Science Advisor. One significant conclusion of that study is that there is a pervasive lack of the underlying basic knowledge in this field, and that a first priority should be to build a classical research community through increased government support of basic research at universities.

Although it is dangerous to generalize from one study, it seems fairly obvious that university research has fallen behind the applications of some of the newer technologies in industry; and that the development of classical research communities in the fields underlying today's industrial applications is essential if we are to continue to make progress.

It is important to note a significant difference in current initiatives (undertaken by the NRC and COSEPUP) and many previous activities. There is a great deal of involvement by people from industry in the current activities, whereas this was not true in the past. Thus, the directions for the proposed engineering research directly reflect the needs of industry, and not merely the desire of the academics.

In summary:

a) There needs to be an increase in the level of government support for engineering research, with special recognition of research teams involved in "big research," in addition to the support of individual investigators.

b) The engineering community--from industry as well as from academe--needs to determine which areas of research will be those that are the most important to pursue, and advise the government accordingly.

4. Engineering Equipment

Not long ago there was a view that the equipment used in engineering education should be no older than the students who were using it. Not so, anymore. The equipment used today has three things in common: it is highly complex; it is difficult to maintain; and it becomes obsolete quickly, often in three to five years.

Undergraduate education today requires easy access to computers and computer-aided-design laboratories, to laboratory practice in the application of microprocessors, to all sorts of laboratory instrumentation that is driven by computers, and to the analysis of laboratory results with sophisticated computational capabilities. It is not unusual to have an investment of several millions of dollars (in hardware and software) in an undergraduate computer graphics laboratory, with annual operating expenses of the order of one million dollars.

At the graduate level, as pointed out earlier, much of the research is becoming "big research." This means that research equipment is becoming enormously expensive. A single piece of equipment may easily cost a million dollars, while a research team working on a related set of problems may require a laboratory investment of several millions. At the same time much of the laboratory space at our universities is out-of-date, and cannot provide the proper environment for today's sensitive instrumentation (e.g., cleanrooms, vibration isolation, etc.).

The costs of operations are also increasing rapidly with the advent of big complex pieces of equipment. No longer can faculty members and their graduate students keep all of the equipment in running order. Instead, substantial numbers of highly trained technicians are needed.

In summary:

a) There is a need to upgrade, on a continuing basis, the equipment and instrumentation used in undergraduate teaching as well as that use in research.

b) There is also a need to provide for the maintenance of that equipment and instrumentation, and for the space in which it is housed.

c) The costs for doing this are generally beyond the "tuition budget," and beyond those provided for individual investigators.

Mr. LUNDINE. Thank you very much. I think I will defer my own questioning, and if there is time, I will conclude with it.

Mr. Mineta, do you have any questions?

Mr. MINETA. Thank you, Mr. Chairman.

Mr. Young, thank you very much for your testimony. When you talked about the R&D projects, you said something about their having just fell off the list. Is that because those are not high priority as, let us say, that company might consider, or is it because it is a long-term low-payback kind of program, so the company decides not to get into it. It still does not really measure the importance of that effort, but it is just one of, Is it worth putting the money in and what do we get out of it kind of a thing?

Mr. YOUNG. My response must be taken in the context of a profitable organization and one that most likely has some kind of an ongoing research and development program. I know this is certainly the case among our own divisions. If you go around the corporate laboratories, and you ask them "What are the things you would like to work on?" what you will reproduce is a list of all the things right off the bottom edge of what they are doing themselves. The things that are really important, they are moving ahead with them and that have a direct application and a direct payback. I rather think that is the general character of things. The things that are really important, you tend to apply your research and development money to first.

Mr. MINETA. That is my question, though: They are important, and direct payback, the relationship that makes the decision, rather than something that may be worthwhile but it is going to be, again, a low payback, long-term kind of thing.

Mr. YOUNG. All I am cautioning you is that the danger is that what you will reproduce is a list of second order priority items. I am just flagging that potential danger.

I do agree, though, that there may be some shared sets of things that could be pursued that maybe have longer term paybacks or bigger investments that companies might be willing to do on their own. I have been quite impressed, frankly, with how effective the Semiconductor Research Corp. has become. This is like a co-op, in which a very large number of the participants in the semiconductor industry have voluntarily gotten together, and with the promised antitrust relaxation coming along, have ventured forth with the understanding that their activities are likely to be viewed in a favorable legal context and have begun to undertake a cooperative effort.

I assure you, there is no more industry than semiconductors that is characterized by the enthusiastic entrepreneur, and we-can-do-anything-on-our-own kind of mentality. Literally in the 3 years that this has been underway, we find a tremendous enthusiasm for joint efforts, working together, putting money back in the research universities, but also finding ways in which they might work together in cooperative projects. So I think there are some other ways for dealing with the genuinely important questions than going around and maybe asking the Government to fund those. I suggested that maybe funding symmetry was something to be looked for. A way, perhaps, would be if companies joined together and decided to fund a certain technology area, it might be to complement that as a way of assuring that, (a) it is important, and (b) it has a self-aligning feature of working along.

Mr. MINETA. Are we putting too much money into basic research and not enough into production research, in the public or the private sector, but especially in the private sector since that's really where it ought to be done.

Mr. YOUNG. My view is that probably the level of basic research has been coming up over the last 3 or 4 years, after a period in which I believe it was trending downward. I think that is the right public policy. That is not to say that there are not other additional projects, in terms of a more applied use of that, taking it to the next step of steering it toward commercial applications from a technology-development point of view, that might also be appropriate.

I think the level of funding of research and development in the country is really not all that high. I think as Congressman LaFalce observed, one-half of the funding, about $40 billion out of the $80 billion we spent this year, was spent by the Federal Government, two-thirds roughly by DOD, 15 percent by NASA. I think it is quite arguable how directly applicable that kind of research is. Yes, there is some spillover, but it really is not the same as a dollar spent by the private sector. If you compare our country's total expenditures for R&D with those of our leading competitors, and you remove that factor, or factor it down in some appropriate way, I do not think we are spending too much and probably not enough.

Mr. MINETA. It seems to me that back in the 1972 to 1974 era, as the economy was declining, the amount of money we were putting into R&D was declining as a percentage of sales.

Mr. YOUNG. Right.

Mr. MINETA. In the meantime, the Japanese were pretty consistent in how much they were putting into R&D, so that by the time the market came back in 1975, 1976, and 1977 they were hitting the road running, whereas at that point, as the economy started to turn around, then our companies said, "Yes, we have to start putting money into R&D." But we were always behind that curve, in terms of what was happening in the marketplace, whereas they had already put their money into R&D. How do we handle the peaks and valleys with some consistency in terms of what we are doing so that it is not a stop-start, hot-cold kind of an effort?

Mr. YOUNG. I do not know the answer to that. Some industries are extremely cyclical, semiconductors being one of those. It is hard to separate all of these effects. The cost of capital, in terms of Japanese competition in semiconductors, has been probably as great a factor as perhaps some of the effects you have alluded to. Certainly in our own company, we have a very stable kind of R&D spending level, and it does tend to fluctuate as a percentage of sales, but the spending growth is just about the same. We try to do our college recruiting every year, and it is one of those factors which we believe is very much of a long-term effect and should be stabilized.

I think most companies tend to run things that way, but some companies that are highly cyclical in their business cycles simply cannot afford to do that.

Mr. MINETA. Thank you very much.

Mr. LUNDINE. Mr. Gregg.

Mr. GREGG. I yield.

Mr. ZSCHAU. I would just like to thank you, John, for your comments. Even though you did not comment on the bills before us today, let me just ask you a question about them. Generally speaking—and I know it is an oversimplification to describe it this way—they address the issue of enhancing our technological development by establishing some sort of a government organization that would study the problems and indicate where the opportunities are and, in some cases, fund some development and promote communication and so forth. Do you feel, one, a need for that kind of change in government organization, and two, do you think that sort of thing could be effective in promoting technological advances?

Mr. YOUNG. That is a pretty general thing to respond to, and I have read a synopsis of these bills. I think there is a thread through some of the intent there that probably is a policy direction that is not inappropriate. I think there could be some carefully managed technology support, let us say, manufacturing technology development in the same sense of the word of developing capabilities. Many industries and firms could draw from that to refurbish or enhance the technological base of the country.

I am skeptical about an entire new institution required to do that. I think there are some models like NSF, and in fact there has been quite a remodeling of NSF going on, to tilt engineering up to full parity with the science side that would have the capability of perhaps dealing with these kinds of questions on exactly the kind of peer review technology-based process, as opposed to the political environment in which this kind of thing is apt to go on or made part of some major administrative function. I just think that it is extremely important to come back to fundamental principles, looking at how to organize this kind of activity.

Mr. ZSCHAU. Thank you.

Mr. LUNDINE. Mr. Ritter.

Mr. RITTER. Thank you.

As the problem comes across, the problem is that somehow the vast amount of research and development does not get into products, does not get into markets, it does not get into competitiveness. We do a lot, but as you say, the DOD takes off a big chunk, Space takes off a big chunk. Yet we have an existing structure to perform research which is probably second to none in the world. As a matter of fact, the Japanese are still coming over here, getting their basic and first experiences in American research facilities. As you pointed out, our major research universities are the lynchpin of this, and that is where the Japanese people are getting their doctorates, most of the key people that go back and then apply it.

Is it not time that we stimulated on the university side a greater connection between those universities and the private sector in a way in which the markets and the products and the more timely considerations of competitiveness got into that marvelous system of performing research? For example, we in our task force have thought about the idea of expanding the R&D tax credit to the university-industry connection at a level which is higher, perhaps, than even that which exists in the industry itself. Some kind of special incentive to connect further the university capabilities with the industry, or some kind of incentive, without setting up a new bureaucracy—and NSF could be involved, as the engineering side tilts upward. But is not the problem really connecting that capability more closely with the private sector, in the final analysis, and not so much more government involvement, government intervention, and government direction. What do you think some of the mechanisms could be for enhancing through the incentives process the connection between those research institutions decentralized and the decentralized needs of the private sector. That is both a comment and a question.

Mr. YOUNG. I understand that, and I would like to say that your own sense of understanding about the special relationship between universities and the private sector and recognition of universities for the pivotal role they play was certainly contemplated by the President's Commission on Industrial Competitiveness. The recommendation we made, coming out of our full Commission, was that there be a special incentive for university support.

If you remember how the tax credit works, there is a rolling base. You take the trailing 3 years and then the increase this year over the trailing 3-year base, and 25 percent of that becomes your tax credit. Well, with respect to university research, at least one way of doing this would be to have a fixed-base period so that over time your incentive to continue to fund more extensively university research would have a growing incentive. As I say, we do not hold any great brief that this is the only way, but I think it telegraphs the intent rather clearly.

Let me say a few words about coupling. I am afraid I will have to show my parochialism by being next door to Stanford. But I think there is at once a lesson there, because the interaction between Stanford and our company and the many companies in the Silicon Valley is well known. I think this interaction is perhaps very much more developed and at the leading edge of what is possible.

Government has done a lot of funding. You should realize that probably 95 percent of the research money that comes to a place like Stanford still comes from the Federal Government, even though there is a lot more private-sector activity going on. But there was no ability to fund bricks and mortar. I chaired a small group to raise from 19 companies about $15 million to get a center for integrated systems established at Stanford. It is the bricks and mortar that gives the state-of-the-art VLSI facility. It establishes also an on-going research board from members of those companies that participate on campus and help to steer the research program.

Again, it has this kind of channelizing effect on a lot of other government money. There is a lot of government R&D money that will go through there, but the program selection and steering I think would be modified a great deal because of this interaction, coupling, and so forth. Resident scholars from companies can be on campus, working right with the post-docs and faculty members as part of this research team. That is one kind of a model, and it seems to be going very well. In fact, President Mitterrand from France was hosted by Don Kennedy, the president of Stanford, and me at the center just about 2 months ago when he had his visit here, and he was very interested.

Mr. RITTER. He was impressed?

Mr. YOUNG. He was very impressed by this approach.

Westinghouse, for example, along with Carnegie-Mellon, has a joint manufacturing technology research program—again, company and university people working together. This has been a kind of leverage point. That is one of the two universities that has a decent graduate program in manufacturing technology.

We are working right now at Stanford on a center for genetic and molecular medicine, a $40 million project, again to get the private sector along with all the biotechnology people. It is a way of accelerating, turning scientific discoveries into real human treatable kinds of forms and leveraging them. So there are a lot of things going on that perhaps could be accelerated by matching money or that kind of thing. But I think it is the primary role of a government program to decide in advance that these are the things you ought to do that is the real danger. It ought not to be the pusher but maybe the trailer in funding.

Mr. RITTER. If I may comment there, I think the need for engineering research and the satisfying of the need for a greater balance toward engineering research and advanced technology research would be taken care of if the stimuli were there. If we are looking to enhance something, let us not enhance the highest level of the pyramid, but let's enhance the communications down there at the building blocks.

I would like to close with a plug for MIT, being a product of that other end of the country, the Northeast, which still is showing some great vitality these days, as well as the Silicon Valley. There are a number of programs at MIT and Lehigh that really have gotten down to these ideas of greater coupling. If we could at the Federal level see to it that the incentives are there, we may solve a lot of the problems that these six bills attempt to address.

Mr. LUNDINE. Mr. Young, I understand that we had a commitment to get you out of here by a quarter of 11. We have extended that, even though Mr. Gregg and I both passed our own opportunity to question. If the measure of somebody's insight is leaving a lot of questions that we would like answered, you have certainly achieved that.

Mr. YOUNG. I am willing to stay a few more minutes. I came out here to deliver this testimony, and whatever is getting deferred is probably the right order of things. If there are any further questions to respond to that I can be helpful with, I would like to.

Mr. GREGG. In your facts, you use terms like "diversity," "lack of predictability," "dynamic and mobile," "small group initiative," "innovation," "fluidity," and "flexibility." Are these not all fundamentally alien to the bureaucracy in the Federal Government? How can the Federal Government get into the business of technology, applied technology and the commercialization of technology if that is the core that it takes to produce it?

Mr. YOUNG. I think very carefully. That is the character of the beast. I think one has to be very careful in architecting some kind of a system that complements that kind of goal. Again, I think the idea is increasing the strength of the technology base; there probably are some mechanisms. For example, the new centers of excellence for manufacturing technology that I think are going on through NSF might be the kind of nucleii around which more companies might join together to have joint research programs or work cooperatively. I think there may be some mechanisms, but they have to be looked at very carefully, and they should pass that test. Otherwise, I am very fearful that we are going to build in more structure, more politics, and spend more money, but get very little for it.

Mr. **Lundine.** I would like to share an experience and then ask for your comment. I had the opportunity late last year to go out to the Battelle Institute in Columbus, OH. I do not know if you are at all familiar with what they do. It essentially got started with private grant, and as I see it, it is at that fulcrum between research and development that is commercially acceptable because they are actually doing contracts for steel companies and small tiny businesses in Columbus and all sorts of other things, and the university research to which it is very closely related at Ohio State.

It strikes me that we need, somehow, more Battelles that are in that position, where they can do advanced metallurgy that no steel company could do on their own, part of which might be paid for by the steel companies. I am just using that as an example. Part of which probably you need some kind of funding, which Battelle does through internally-generated funds. Would you agree with that, without regard to what the Government ought to do, that we need some additional institutions that are at that midpoint between university research and what you people ought to be doing in the private sector?

Mr. **Young.** There probably is a role, and there are other organizations, SRI being one, that do fill that kind of a role. But the driving point might not be the formation of the institution so much as the enabling legislation to have companies join together to do cooperative research. Having done that in the steel industry, for example, then you might decide, "We need a vehicle to do that or augment what we can do on our own" or whatever. That might be the funding drive that would be stimulated by literally deregulating the marketplace, if you want to think about it that way, in a way that would allow companies to make a wider set of choices on how to execute needed R&D.

Mr. **Lundine.** Thank you very much, Mr. Young. We appreciate your contribution.

Congressman Zschau, I think you are the next witness.

STATEMENT OF HON. EDWIN V.W. ZSCHAU, A U.S. REPRESENTATIVE FROM THE STATE OF CALIFORNIA

Mr. **Zschau.** I want to begin, Mr. Chairman, by thanking you and this subcommittee for this opportunity to testify. I am not going to take a long period of time, but I did want to make some comments about the bills being considered in this particular hearing.

Before I start, I would like to commend the chairman of the subcommittee and its members for the work that the subcommittee has been doing on this particular issue. I think this is the fourth time that I have had the opportunity to appear before the committee, and it indicates the level of work and the intensity of effort that the committee has been following.

About 15 months ago, I had the privilege of being aboard the yacht *Britannia,* which is the Queen's yacht. It was docked in San Francisco Bay. Queen Elizabeth was visiting the California area. She came up to me during the reception there and asked me a most provocative question. She asked me: "Why is it that there are so many high-technology companies all in one area, the Silicon Valley?" She had just visited the area that day, and she was impressed by how many were all in one area.

Certainly, that is the case. There are about 700 high-technology companies in what is known as the Silicon Valley area.

It goes back to 1905, when Lee deForest invented the vacuum tube, and then there were the Varian brothers that invented the klystron tube that formed the basis for microwave communication. Dave Packard and Bill Hewlett, started H-P in a garage in 1939, and as John Young just said, a company that will have 80,000 employees soon was generated there. They really created an example for others in the area.

William Shockley left Bell Labs to come there and started the Shockley Laboratories to exploit the transistor invention for which he and others received the Nobel Prize. And there a young engineer, Bob Noyce, got the idea of putting several transistors on a chip and invented the integrated circuit. He started a company, Fairchild Semiconductor, that spawned many others. Then he left that to start Intel that developed the microprocessor. And many other microprocessor companies developed there.

There were a group of experimenters around Stanford that started a club called the Home Brew Computer Club, who made their own computers with television sets, microprocessors, and keyboards, and two members of that club, Steve Jobs and Steve Wozniak, formed a company, Apple Computer, that in a short period of time became a billion-dollar company. And so it goes, the stories of company after company.

The reason why I describe these stories is that they revolve around people. They do not revolve around institutions. They do not revolve around government programs. They revolve around people, personalities, wanting to try new ideas, take risks, to develop new technologies. So, in answer to the queen's question, "Why is it that so many started there?"— you have to look at the environment, the educational institution, and the example that Bill Hewlett and Dave Packard provided. When answering the queen's question, perhaps the more important questions to ask are: How can we make this keep happening? How can we make technology advancement continue? How can we make it happen in other places outside the Silicon Valley throughout the country?

The bills before us deal with this issue. Their objective is to promote technological advancement. Their objective is to promote the application of technology. But I would agree with John Young. I have a skepticism that they would be able to achieve those objectives. In particular, they seem to me to demonstrate what I guess is a trap that those of us in government often fall into: problem-solving by agency.

That is, if you see a problem, and you do not really know how to deal with it, what you do is create an agency or an organization or a board. You give it a mandate to solve that problem that you do not know how to solve, and then you provide what you think is enough money to provide the staff and so forth.

But that does not really deal with the issue. That is, it does not reflect an understanding of the problem. I guess that is why I would say that I am skeptical that these particular organizations would be effective. I do not feel that the approach to solving problems by agency is anything more than giving us in the legislative branch the opportunity to say, "I guess we have done our job. We have created an agency to solve the problem. We have funded it, and now we can go on to the next problem."

I can say this and I can talk about my skepticism because I used the same approach in my company. Let me tell you the story about it.

We were a company about 2 years old. We had achieved a sales level of about $2.5 million in a particular product area, and the board of directors of my company suggested to me, "Ed, why don't you bring in a consulting firm to analyze the business and then tell us how we can grow to be a large company—how we can really capture new markets." So I brought in the firm from New York which is considered to be one of the experts in strategic and market planning.

They did a careful analysis of our strengths—which were few—and our weaknesses—which were many—and came to the conclusion that the current product line that we had would be phased out within 18 months. They said, "There is no market opportunity there. Within 18 months the competition will be so great that you are not going to be able to survive in that market, and what you should do is enter a completely new market."

So I followed their advice. They had a very thick plan and a fancy presentation. I devoted all the resources we had in the company to the new market area. The only thing I did with the old product line was, I assigned a manager to it and I said, "Why don't you keep it going as long as you can? Don't expect it to last more than 18 months or 24 months, but keep it going as long as you can."

Well, the new business never materialized. They were wrong about the opportunity. In fact, putting all of our resources in there almost sunk us. The old business, however, grew very rapidly. And now, where it was a $2.5 million business some years ago, it is now over $100 million, a part of the company that I left recently.

It indicated to me the ridiculousness of saying, "If we do not understand the problem, let's bring in a consulting firm" or the ridiculousness or the folly of saying, "If we don't know how to advance technology, let's set up an organization to do it." It just does not work, in my opinion.

Well, what does work, or what is the role of the Government? That is the question we have to ask. The task force that Don Ritter and I chair, the Task Force on High Technology Initiatives, part of the Republican Research Committee, has made some proposals about what the proper role of Government is. We have documented those proposals in a little booklet which, if it would be possible, Mr. Chairman, I would like included in the record at this point.

Mr. Lundine. That will be included in the record.

[The booklet mentioned above follows:]

Targeting the Process of Innovation

An Agenda For U.S. Technological Leadership And Industrial Competitiveness

Recommendations Prepared By:
The Steering Committee of
The Task Force On High Technology Initiatives
House Republican Research Committee
U.S. House of Representatives
First Edition, May 1984

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Executive Summary

America's challenge today and for the future is to create enough new and satisfying jobs to employ our growing work force and to increase the standard of living for all Americans. The key to meeting this challenge is industrial competitiveness—developing and producing products and services whose quality and prices make them attractive to consumers abroad and those here at home.

Under President Reagan's leadership, the United States today is experiencing strong, broad-based economic growth. Nevertheless, some American industries have lost their competitive edge. U.S. firms have been beaten out in foreign markets, and they have lost market share here at home. This has cost American jobs.

Some suggest that this is a permanent condition. They say that America should "write off" industries that have lost ground and concentrate solely on new "sunrise" industries.

We disagree. We believe America can improve its competitiveness in those traditional industries that still have growth potential worldwide. However, to do so American industries will have to *exploit change* rather than fight it. U.S. firms will have to operate in new and better ways. They will have to offer improved products and services. They will have to find techniques to increase worker productivity and product quality. In short, American industries must apply far more technology and innovation, and they must improve the utilization of manpower.

U.S. leadership in technology and its applications has been a primary source of increased competitiveness and new jobs in the past. We must preserve our leadership. But the creation of new technologies and innovation can't be *forced*. Creative ideas, improved products, new companies, and revitalized factories don't spring from government "targeting" of technologies or industries. Rather, they are the product of individuals with vision, genius, and the courage to take risks. As such, innovation can only be *fostered* by an economic environment that encourages individuals and growth.

We believe that the proper role of government in promoting U.S. technological leadership and industrial competitiveness is to *"target" the process* by which new ideas and products are developed—*the process of innovation*. That is, our government should focus on creating an environment in this country in which innovation, new ideas, and new companies are likely to flourish and in which firms in mature industries can modernize. Making sure that such an environment exists is the best way government can help America maintain its technological leadership and industrial competitiveness.

There are four conditions needed for an environment that promotes innovation:

- *A strong commitment to basic research,* deepening and broadening our understanding of fundamental processes that will form the basis for industries, processes, and products in the future;
- *Incentives for investors, entrepreneurs, and innovators* to provide the capital and take the personal risks associated with making technological advances, developing new products, establishing new companies, and rejuvenating mature industries;
- *A strong educational capability,* particularly in the sciences, that assures an ample quantity of trained technical and managerial personnel and a broad base of educated and well-trained citizens who can meet the challenges of a rapidly changing world;
- *Expanding market opportunities,* domestic as well as foreign, which require a healthy domestic economic environment and aggressive trade policies.

Proper government policy for industrial competitiveness is one that focuses on these prerequisites for innovation. It consists of specific legislative and regulatory initiatives that foster these conditions and avoids government actions that would weaken them. The specific initiatives needed will vary as actions are taken and events unfold, but there are specific actions that can and should be taken right now.

This Agenda for U.S. Technological Leadership and Industrial Competitiveness contains 14 legislative initiatives that we believe the 98th Congress should take in 1984 to strengthen the elements that are fundamental to the process of innovation. We have limited this first edition of the Agenda to specific proposals that can and should be implemented in 1984. All of the initiatives recommended in this Agenda are designed to improve the climate for innovation. We believe each is important and would make a meaningful difference. However, we believe one recommendation—reducing the enormous projected federal budget deficits—stands out above the others in its impact. The other proposals will only be fully effective in a healthy domestic economy which cannot survive continued deficit spending of the magnitude now projected.

BASIC RESEARCH
RECOMMENDATIONS FOR 1984

- Increase emphasis on civilian basic research as recommended in the President's FY85 budget;
- Offer a 25% tax credit for corporate funding of research in colleges and universities;
- Modify antitrust laws to require that R&D joint ventures be judged by their competitive effects only and reduce the potential liability for damages from treble to actual damages.

INCENTIVES FOR RISK TAKING
RECOMMENDATIONS FOR 1984

- Make permanent the R&D tax credit and make it applicable to software and start-up companies;
- Make permanent the moratorium on Treasury Regulation Section 861.8;
- Modify antitrust and intellectual property laws to require that the courts consider the effects of competition when judging alleged patent misuse by a patent holder and alleged antitrust violations in the licensing of intellectual property;
- Permit enforcement of a domestic process patent against a product made without proper authority in a foreign country by the patented process;
- Extend intellectual property law to include semiconductor designs and masks.

PROVIDING TRAINED PERSONNEL
RECOMMENDATIONS FOR 1984

- Offer tax credits and enhanced deductions to corporations contributing state-of-the-art scientific equipment and related support services to colleges and universities for educational purposes;
- Permit foreign nationals who possess critical skills which are in short supply in the U.S. to remain and work here.

EXPANDING MARKET OPPORTUNITIES
RECOMMENDATIONS FOR 1984

- Create a new export incentive to replace the Domestic International Sales Corporation (DISC) that the U.S. has agreed to discontinue;
- Instruct our trade negotiators to seek elimination of trade barriers and extension of the GATT to cover investments and services;
- Focus and streamline export controls so they are more effective in preventing the trade-related transfer of militarily critical technologies to our adversaries while avoiding unnecessary obstacles to exports;
- Take actions to reduce substantially the projected budget deficits for FY1985 and beyond.

Enhancing U.S. Technological Leadership and Industrial Competitiveness

America's Challenge: Jobs and Prosperity

America's challenge today and for the future is to create enough new and satisfying jobs to employ our growing work force and to increase the standard of living for all Americans. The key to meeting this challenge is industrial competitiveness—developing and producing products and services whose quality and prices made them attractive to consumers abroad and those here at home.

Under President Reagan's leadership, the United States today is experiencing strong, broad-based economic growth. Nevertheless, some American industries have lost their competitive edge. U.S. firms have been beaten out in foreign markets, and they have lost market share here at home. This has cost American jobs.

Some suggest that this is a permanent condition. They say that America should "write off" industries that have lost ground and concentrate solely on new "sunrise" industries.

We disagree. We believe America can improve its competitiveness in those traditional industries that still have growth potential worldwide. However, to do so American industries will have to *exploit change* rather than fight it. U.S. firms will have to operate in new and better ways. They will have to offer improved products and services. They will have to find techniques to increase worker productivity and product quality. In short, American industries must apply far more technology and innovation, and they must improve the utilization of manpower.

U.S. Technological Leadership Has Helped Create Jobs

Over the past several years, a variety of studies have documented the importance of technological innovation to our economic growth, productivity, job opportunities, and trade competitiveness. A study by the Massachusetts Institute of Technology estimated that 80 percent of the growth in the gross national product of the United States between 1909 and 1949 was due to technological change(1). Further, a recent Commerce Department study found that during the 1970's, the productivity growth rate in high technology industries was more than six times the average of U.S. business. During the same period, employment in high technology and support industries grew more than 50% faster than the growth in total U.S. employment(2).

In recent years, while the overall export performance of the United States has not been good, exports of technology-intensive products have shown excellent growth. From 1970 to 1980, these industries increased their export surplus from $10.4 billion to $42.4 billion per year. During the same period, the trade balance of industries without technological bases declined from near zero to a negative $21.5 billion per year(3). Since each $1 billion of exports results in about 25,000 jobs for Americans, it is clear that American technological leadership in the past has enabled the United States to create many new jobs(4).

U.S. Technological Leadership is Being Challenged From Abroad

On January 25, 1983, President Reagan in his State of the Union message announced that "This Administration is committed to keeping America the technological leader of the world now and into the 21st century." This commitment by the President to spur technology may have come just in the nick of time. U.S. technological leadership has lost momentum in recent years. It hasn't been squandered like some other resources through overuse and waste. It's been frittered away through neglect.

During the 1970's, research and development (R&D) expenditures as a percent of gross national product (GNP) declined about 10% in the United States, reaching a low in 1977-78 of 2.23%. At the same time, our two most aggressive trading partners—Japan and West Germany—increased their R&D expenditures as a fraction of GNP by 20% and 21% respectively. Fortunately, the U.S. trend has reversed since 1978, and in 1983, R&D as a fraction of GNP is estimated at 2.65%—about equal to Japan and West Germany. However, since the U.S. conducts much more defense-related R&D than the other two nations, figures for *civilian* R&D are presently about 30% higher for Japan and West Germany(5).

The lower intensity of our research efforts in the 1970's appears to have contributed to a decline in our leadership in contributions to engineering and scientific advances. Domestic patenting by U.S. inventors declined by 24 percent during the period 1972-81, while U.S. patents to foreign inventors increased(6). U.S. market share of technology-intensive products also fell, from 23.1% in 1970 to 19.9% in 1980(7).

Central Planning Isn't the Answer

Due to the outstanding performance of the U.S. high technology industries plus the growing recognition that U.S. leadership in technology and its applications are being threatened from abroad, high technology and industrial competitiveness issues have been receiving considerable attention in Congress recently.

This is good, but in its enthusiasm to help, Congress must avoid the temptation of promoting direct government involvement of targeting "winners" and "losers" in American industry. The dismal results of the British experiment in central planning and the recent U.S. experience in government "assistance" to synthetic fuels, for example, should illustrate the fallacy of that approach. Still, the House Banking Committee recently passed a bill which proposes forming a Council for Industrial Competitiveness and an associated Bank for Industrial Competitiveness. These new agencies would be charged with formulating a "broad industrial strategy" by providing billions of dollars in federal funds to targeted companies(8).

We believe such a scheme would be doomed to failure. Bureaucrats in Washington, D.C. should not be given the job of picking between opportunities and dead ends. Making such decisions is hard enough for investors or managers in the private sector who are on the firing line and have much to gain or lose personally from the results. Besides, politics would undoubtedly play a major role in the decisions of the Bank and Council. The history of federal handouts indicates that the money is often given to the industries and regions who are best represented in Washington rather than on the basis of merit. A similar conclusion was reached by the Joint Economic Committee after extensive hearings were held on industrial policy last year.(9)

A recent Price-Waterhouse survey of over 400 companies—mostly small and mid-sized firms—showed that business people understand the folly of such government intervention. Less than five percent of those surveyed supported the approach of government finance banks or industrial targeting(10).

Government Should Target the Process of Innovation

The federal government can play a role in promoting U.S. technological leadership and industrial competitiveness, but we believe it should be a "targeting" of a different kind. Rather than targeting specific technologies or industries, the proper role of government is to *target the process* by which the new ideas and products are developed—the *process of innovation*. That is, our government should focus on creating an environment in this country in which innovation, new ideas, and new companies are likely to flourish and in which firms in mature industries can modernize. Fostering such an environment is the best way government can help America maintain its technological leadership and industrial competitiveness.

There are four conditions needed for an environment that promotes innovation:

- *A strong commitment to basic research*, deepening and broadening our understanding of fundamental processes that will form the basis for industries, processes, and products in the future;
- *Incentives for investors, entrepreneurs, and innovators* to provide the capital and take the personal risks associated with making technological advances, developing new products, establishing new companies, and rejuvenating mature industries;
- *A strong educational capability*, particularly in the sciences, that assures an ample quantity of trained technical and managerial personnel and a broad base of educated and well-trained citizens who can meet the challenges of a rapidly changing world;
- *Expanding market opportunities*, domestic as well as foreign, which require a healthy domestic economic environment and aggressive trade policies.

Proper government policy for industrial competitiveness is one that focuses on these prerequisites for innovation. It consists of specific legislative and regulatory initiatives that foster these conditions and avoids government actions that would weaken them. The specific initiatives needed will vary as actions are taken and events unfold, but there are specific actions that can and should be taken right now.

An Agenda for 1984

The following Agenda for U.S. Technological Leadership and Industrial Competitiveness contains 14 legislative initiatives that we believe the 98th Congress should take in 1984 to strengthen the elements that are fundamental to the process of innovation. We have limited this first edition of the Agenda to specific proposals that we think can be implemented in 1984. As such, it does not address many other important factors affecting innovation including K-12 education, worker training, employee incentives, cost of capital, and technology commercialization. Recommendations on these and other factors will be offered in future editions of this Agenda.

A STRONG COMMITMENT TO BASIC RESEARCH

America must renew its commitment to basic research. The federal government must continue to increase its funding of research carried out in universities and research laboratories. The truly basic research—such as the study of DNA that eventually resulted in gene splicing technology which spawned the genetic engineering industry—will normally not be pursued by the private sector because it is not related closely enough to specific products. Funding such research is a proper role of government. Federally funded basic research performed in America's colleges and universities also helps to train the scientists and engineers needed for teaching and future research.

We support the Administration's increased emphasis on civilian basic research in the FY85 research and development budget recommendations, and the stepped-up commitment to integrating the resulting new knowledge into the private sector.

We also believe that closer relationships between research universities and American industry should be encouraged. Closer ties would better expose researchers to the problems and opportunities that American firms face and might result in speedier application of research results to practical situations.

One way to foster better university relationships is to encourage greater corporate financial support of university research. Legislation offering a new 25% tax credit for corporate funding of research in universities and other non-profit institutions would do that. It would also reduce the enormous dependency that universities have today on federal funding of basic research.

INCENTIVES FOR THE RISK TAKERS

In addition to basic research, the U.S. needs more incentives for the risk takers—the investors, entrepreneurs, investors, and enterprises who must take the risks of pursuing new ideas. Here, tax policy and regulatory policy play a significant role.

Tax Policy

The reduction of the capital gains tax rate, passed by Congress in 1978, illustrates the enormous impact that tax policy can have on the availability of risk capital for the financing of new ventures. In 1978, the maximum tax rate on capital gains was reduced from nearly 50 percent to 28 percent. During the eight years prior to 1978, less than $50 million in new capital was made available each year to venture capital funds investing in small companies. However, within eighteen months after the capital gains tax was reduced, $1 billion in new capital was made available to such funds. The maximum capital gains rate was lowered again in 1981 to 20 percent, and in 1983, $4.1 billion of new venture capital was made available from investors(11).

In addition to incentives for investors, the U.S. needs improved incentives for corporate risk taking. The Economic Recovery Tax Act of 1981 contained such an incentive—a 25 percent tax credit on *increases* in research and development expenditures.

This tax credit was an excellent idea. It appears already to have had a positive effect on research and development expenditures. Although the R&D credit was only partially phased-in during 1981 and 1982, a recent McGraw-Hill survey showed that despite the severe recession during that period, there was a significant increase in R&D spending during those years, making it the first post-war recession in which the pace of research spending did not decline(12).

The R&D tax credit can be an important incentive for innovation in all industries, but the restrictions that were placed on the credit by Congress and the Treasury Department have hampered its effectiveness. They have limited the credit's applicability for start-up companies and computer software, and, most importantly, the tax credit is only temporary. It expires on December 31, 1985. However, since most R&D projects are long-term in nature, a temporary R&D tax credit may not provide an adequate incentive for such projects. Congress should pass legislation this year to refine the applicability of the R&D credit and make it permanent so that companies can be assured of the credit's scope and availability when planning long-range projects.

Also, Congress should make permanent the current moratorium on the research and development portions of Section 861 of the tax code. Section 861.8 requires U.S. firms with overseas operations to allocate a percentage of their U.S. R&D expenditures against their foreign source income. This allocation, which denies U.S. firms the full tax benefits of conducting R&D in the United States, has caused U.S. multinational firms to perform more R&D abroad. Making the moratorium on Section 861.8 permanent would keep more R&D jobs here in the U.S.

Improved mechanisms are needed to attract capital to companies that have not been profitable in recent years but which could regain their competitiveness through retooling and modernization. The investment tax credit was enacted more than twenty years ago as an incentive to invest in new capital equipment. Unfortunately, it has not been effective for some of the companies that need it most. Although some companies have made large investments in capital equipment, they often have not earned sufficient profits to use all their tax credits against their liability. This increases their after-tax cost of capital and places them at a competitive disadvantage, particularly against competitors in countries where the cost of capital is lower. The Task Force will hold hearings on the capital formation problems of the ailing industries with the intent of proposing specific actions later this year to address the problems.

Patents and Copyrights

In addition to tax incentives, patent and copyright laws need to be strengthened to insure that innovators—both private and corporate—can receive fair rewards for their ingenuity. Often, the most efficient way to bring a new technology to market is by licensing that technology to others. Licensing can enable intellectual property owners to employ the capability of established enterprises to market a technology quickly and at lower cost. This can be particularly important for some small businesses that do not have the ability to develop all possible applications of new technologies by themselves.

Unfortunately, the courts have not always been sympathetic to the pro-competitive benefits of licensing. They have ruled against patent holders based on the form of their license agreements rather

High Technology Council, for example, have already established industrial giving programs to collect money from corporations for faculty salaries and equipment.

The federal government has a role to play, too. Tax credits and enhanced deductions for corporate contributions of state-of-the-art equipment and support services for educational purposes should be offered. Such incentives would encourage more private sector support for increasing the capacity of our technical education facilities without requiring a new federal bureaucracy to carry it out.

U.S. immigration policy should also recognize the need for trained technical people. In particular, a high percentage—30% to 50%—of graduate engineering students are foreign nationals. Students who develop technical skills that are in short supply in this country should be permitted to remain here. Immigration reform legislation should continue to permit technically trained foreign nationals to remain in this country to contribute to U.S. technology rather than requiring such students to return to their home countries after receiving their education in the U.S.

We recognize and are concerned about the plight of workers who are unprepared for the changes and new jobs that will be created by advances in technology. The Job Training Partnership Act, which went fully into effect on October 1, 1983, was designed to address this problem. We will be evaluating its effectiveness and will report on its performance as well as suggesting improvements and other job training initiatives in future editions of this Agenda.

PROVIDING TRAINED PERSONNEL
RECOMMENDATIONS FOR 1984

- Offer tax credits and enhanced deductions to corporations contributing state-of-the-art scientific equipment and related support services to colleges and universities for educational purposes;
- Permit foreign nationals who possess critical skills which are in short supply in the U.S. to remain and work here.

EXPANDING MARKET OPPORTUNITIES

Even if the United States has a strong research base, incentives for risk-taking, and well-trained people, innovation and the creation of new jobs will be stifled unless there are attractive business opportunities at home and abroad. That means America must have a strong domestic economy, and U.S. businesses must have access to foreign markets. Government can play an important role in fostering both.

The United States should vigorously pursue a trade policy aimed at achieving free and *fair* trade. The U.S. should negotiate in a tough-minded fashion to break down the trade barriers erected by our trading partners so that American companies can compete on a level, two-way street.

In working to remove trade barriers, we should strive to strengthen the General Agreement on Tariffs and Trade (GATT), the multilateral organization which has done so much in the past to liberalize trade among the nations of the world. In addition, the role of the GATT should be expanded to cover services and investments—two areas of growing importance in today's world. Negotiating with our trading partners to modify the GATT to provide coverage of services and investments would help to improve our balance of payments and protect U.S. investors from damaging interference by foreign governments.

In addition to negotiating for a fair trading environment, government policy should encourage exports by U.S. firms, particularly small businesses. Tax incentives (like the Domestic International Sales Corporation which permit the deferral of taxes on profits from export sales) should be provided to encourage and help finance experts.

Export controls on high technology products should be focused and streamlined to prevent the trade-related transfer of militarily critical technologies to our adversaries while, at the same time, making exporting easier for U.S. companies. Likewise, restrictions on exports to achieve foreign policy goals should be implemented only after carefully considering existing contracts and determining whether they can be effective in light of the availability of the products from foreign sources.

Most importantly, U.S. businesses can achieve their full potential to create jobs if they operate within a healthy domestic economic climate. People are less willing to invest, make long-term business commitments, and borrow the funds needed for expansion when there is uncertainty about the direction of interest rates and inflation.

Congress and the Administration should act with a sense of urgency to reduce significantly the enormous projected budget deficits which are a source of economic uncertainty and distort international exchange rates in a way that damages U.S. export opportunities. We believe reducing the deficits requires a monetary policy that accommodates economic growth, a tax policy that encourages savings and investment, and the discipline to curtail the

Footnotes

[1] *Review of Economics and Statistics,* August, 1957, Harvard University Press, Cambridge, Massachusetts.

[2] *An Assessment of U.S. Competitiveness in High Technology Industries,* U.S. Department of Commerce, International Trade Administration, February, 1983, pp. 4-5.

[3] *Ibid,* p. 43.

[4] Statement by Paul Volcker, Chairman, Federal Reserve Board, before the House Ways and Means Committee, U.S. Congress, Washington, D.C., April 10, 1984.

[5] *Science Indicators 1982,* National Science Board/National Science Foundation, 1983, pp. 195, 197.

[6] *Ibid,* p. 209.

[7] *An Assessment of U.S. Competitiveness in High Technology Industries,* U.S. Department of Commerce, International Trade Administration, February, 1983, p. 44.

[8] H.R. 4360, 98th Congress, Introduced by Rep. John LaFalce, November 10, 1983.

[9] *Industrial Policy: A Joint Economic Committee Staff Study,* U.S. Congress, April 1984.

[10] *Business Views on Competing in the High Technology Era: The Results of a Survey of High Technology Companies,* Price-Waterhouse, Washington, D.C., March, 1984.

[11] *Venture Capital Journal,* January, 1984, Venture Economics, Wellesley, Massachusetts, p. 6.

[12] *28th Annual McGraw-Hill Survey of Business' Plans for Research and Development, 1983-86,* McGraw-Hill Publications Company, New York, May, 1983.

[13] *Technical Employment Projections 1983-87,* American Electronics Association, Palo Alto, California, July, 1983.

[14] Geilse, John W., "The Faculty Shortage: The 1982 Survey," *Engineering Education,* vol. 74, no. 1, October 1983, pp. 47-53.

[15] Statement by the Blue Ribbon Committee on Engineering Education, American Electronics Association, Palo Alto, California, June, 1981.

Mr. **Zschau**. Essentially the concept is, in answer to the question "What is the proper role of government?" to say: Rather than asking government to decide where the opportunities are—that is, targeting on certain industries or technologies or companies or processes—to target on the process by which they develop—the process of innovation. That is, to create in this country an environment in which new ideas, technological advances, new companies are likely to flourish.

We have identified in this booklet four prerequisites for such an environment: a commitment to basic research, incentives for risk-taking, an adequate supply of trained technical people—which speaks to our education system, and ample market opportunities. Without going into the details, let me just say that it is our feeling that rather than setting up new organizations, what we should be doing is analyzing our various policies—our regulatory policies, tax policies, education policies, research policies, fiscal monetary policies, trade policies—and ask ourselves: Are those policies stimulative to the prerequisites for this environment for innovation, or are they detrimental, are they counterproductive?

Then, those of us in the legislative body or those of us in the Administration should alter those policies under our jurisdiction in order to enhance this environment for innovation.

Let me just give you a specific example. Back in the 1970's, venture capital was very scarce. A lot of companies, including my own, were either not getting funded, they were scraping by undercapitalized or, worse yet—and this includes mine—were going over to Japan, selling our technology in order to get money just to meet the payroll. The amount of venture capital available per year at that time in the mid-1970's was about $50 million per year.

In 1978, the late Congressman Bill Steiger led a charge, if you will, in the U.S. Congress to reduce the tax on capital gains. Within 18 months after the tax was reduced from nearly a 50-percent maximum rate to 28 percent maximum rate, $1 billion of new venture capital became available. Every year since then, it has been over $1 billion of new capital. Last year, $4.2 billion of venture capital was made available. We went from $50 million a year during the 1970's, when the tax rate was high, to $4.2 billion last year. The treasury has collected more money in capital gains tax revenues than at that time, I might just add.

The reason I use that example is, we could have said, "Gee, we have a capital shortage in this country. What we ought to do is set up some sort of a government agency, fund it with capital, and have it allocate that money to promising ideas." But rather than doing that, we said, "What we have to do is create an environment in which the private sector will be stimulated to invest." That has had a far more dramatic impact on young companies than the other approach would have.

In conclusion, Mr. Chairman, let me just say this. I think the debate on this issue boils down to a basic question: Who is responsible, who is most capable for creating jobs in this country, for advancing technology in this country, for enhancing economic growth? There are some who say, it is the Government, Government is responsible, Government is more capable, and what we have to do is properly organize it. I would say that it is the individ-

STATEMENT OF REP. CHARLES PASHAYAN, JR., ON H.R. 2525, BEFORE THE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY, JUNE 7, 1984.

Mr. Chairman, I appreciate this opportunity to speak before your Subcommittee on H.R. 2525, legislation that I have introduced which would establish a bi-partisan National Commission on Technological Innovation and Industrial Modernization.

Why do we need a Commission to examine Federal laws, regulations and policies that impact on industrial modernization and entrepreneurial innovation? Why is it necessary for this Commission to make recommendations for changes in these laws, regulations and policies so that our industries can compete more effectively?

The United States, along with the entire industrial world, is experiencing a fundamental change that affects the way labor, materials, capital, and production are used. The result has been that certain industries--the so-called smokestack industries--are not growing and producing and competing as once they did. Other industries--the so-called high technology industries--have taken the lead in growth in the economy. There are profound implications in these changes in the structure of our economy, not only for the future of this country and its global relations, but also for the individual American worker.

Domestic industries operate under a myriad of Federal laws, regulations, and policies. These rules, if you will, have a direct effect on what is produced, how it is produced, where it is produced, the cost of the product, who is employed for the production, the allocation of capital, and the invention and promotion of new products. Although the laws and regulations have been applied by the Federal government in an attempt to satisfy certain policies, to discourage others, to protect the environment, or to conserve jobs, many times the laws and regulations are counterproductive. The effect is more apparent in industry and commerce.

But some of these are so extensive that they affect agriculture, once one of this nation's leaders in our overall balance of trade. To many this may not be obvious, but it is becoming more and more to the forefront as agriculture faces the same problems of job displacement, and the loss of foreign markets. For example, Congress long ago ruled that dairy products should be supported by tax dollars. When that cash transfer became attractive, legitimate dairymen and investors rushed in and produced a surplus, which some have called obscene. At the same time, when we should rationally believe that we could sell the surplus of dairy products, we find that we can only give it away. That which the Federal government has purchased is unsalable on the world market because we have overvalued it for international markets.

In other instances, the rules are outdated. For example, again looking at agriculture, we still hold to a premise that an imported product will not be harmful unless domestic producers can prove and innovative processes are encouraged, not stifled? We cannot have the tax code that discourages investments, or Congress's infusing funds into programs that create artificial surpluses, or trade conditions thwarting the business community's ability to sell that surplus. But because our economy is based on the free market, I do not believe that the Federal government should be in the business of determining what industries should be winners and what industries should be losers. This process occurs through the dynamics of the economy itself.

This then is the mandate of the Commission as prescribed in H.R. 2525. The Commission would be charged with looking at specific areas such as tax laws, support and funding for basic research and development, technical education at the primary, secondary, and postsecondary level, and trade promotion policies.

The Commission would be made up of individuals from manufacturing and agri-business, labor, and academia. The 21 members would be appointed by the President, the Speaker of the House, and the President of the Senate. It would include 2 Members of both Houses of Congress, from the minority and majority parties. They would be required to report their findings to the President and the Congress.

As a Member of the steering committee of the Republican Task Force on High Technology Initiatives, I have been involved in formulating a legislative agenda that describes what Congress can and should do to foster the economic climate in which innovation is rewarded and industrial competitiveness is promoted. While a National Commission is not part of the Task Force's Agenda, I believe that it could provide the forum from which we could continue to monitor the laws, regulations, and policies that impede or promote economic growth, now and for the future.

Statement of Congressman George E. Brown, Jr.
Before the Subcommittee on Science, Research, and Technology
House Committee on Science and Technology

Hearing on Federal Organization for Technological Innovation

June 7, 1984

Mr. Chairman, thank you for the opportunity to testify before you today as you start your series of hearings on federal organization for technological innovation. I would also like to express my appreciation to my colleagues, Mr. Fuqua, Mr. LaFalce, Mr. Pashayan, Mr. Zschau, and Mr. Gorton for their continued leadership and legislative contributions in this area. I hope that this hearing will show that although we may each hold different ideas concerning the role of the federal government in technological innovation, there exist many commonalities in our individual legislative approaches.

We have witnessed a decline in innovation and productivity over the last 15 to 20 years which has contributed to the decline in economic growth. The problems appear to be structural in nature rather than cyclical. They have plagued the economy for more than a decade through periods of both recession and expansion. The agriculture, steel, automobile, housing, and other industries have experienced modest improvements, but rising interest rates jeopardize their tenuous recoveries.

Innovation policies are administered in an ad-hoc and uncoordinated fashion through nine different federal agencies. The 700 government research laboratories lack well defined goals. The Office of Productivity, Technology and Innovation which should be taking a leadership role is understaffed and housed in an agency with other priorities. And while I was pleased to see the "tech" centers mandated by the Stevenson-Wydler Act, which were cut by the Administration, resurface as interdisciplinary engineering centers in the National Science Foundation, progress in implementation of the goals of this Act has been frustratingly slow. Congress has similar leadership problems in contending with the confusing network of subcommitee jurisdictions.

I have introduced two bills with the aim of focusing Congressional attention on ways of providing concerted strategic long-term planning and coordination for technology development. One of these, the Economically Strategic Industrial R&D Act (H.R. 1243/S.428) would authorize a study to be conducted by the National Academies of Science and Engineering to examine emerging technologies in order to determine their potential for commercial exploitation. The study would thus help to identify promising, or "strategic" technologies and a development plan for these would be presented to the President and to the Congress.

My proposal for the establishment of an independent federal technology foundation, called the National Technology Foundation (NTF, H.R. 481) would serve to focus the nation's technology development. The NTF would consolidate, in a single agency, technology-related programs which are currently scattered throughout the Department of Commerce and the National Science Foundation. In their current homes, these programs are fragmented and do not provide a sufficient focus to help develop a national economy in which innovation can thrive.

It is my belief that the legislation I am suggesting can, by more clearly focusing existing resources and authorities, and with very little additional funding or authority, begin to restore our leadership in the global productivity competition. These initiatives might also help define a clear leadership role for the government in enunciating national goals and policies. This could be accomplished without curtailing the dynamics of market-oriented planning by the private sector.

Thank you, Mr. Chairman.

In addition to these transfers of specific programs and agencies, the NTF would be given all the functions, powers, duties, and authorities of the National Science Foundation and of the Secretary of Commerce under the Stevenson-Wydler Technology Innovation Act of 1980.

This bill takes a comprehensive approach to the restructuring and strengthening of Federal programs for the direct support of industrial technology and innovation. A complete enumeration of the NTF's programs and powers would require several pages. It would be able to award grants and contracts to both non-profit and profit-making institutions, as well as to individuals in some cases, for the support of generic research, technology transfer, education and training, cooperative industry/university research, and basic research in engineering. It would provide technical assistance to small business and would serve as a center for information about Federal activites affecting innovation. It would collect and analyze information about the competitiveness of industrial technology and about technical manpower needs. It would help transfer technology from the Federal laboratories to industry. It would perform technology assessments of emerging technologies, study the relationships of technology to economic performance of the Nation, and recommend policy initiatives to the President and Congress for the further support of technological innovation. In addition, of course, it would be responsible for the ongoing activities of the National Bureau of Standards, Patent Office and NTIS.

This list of the main functions of the National Technology Foundation proposal does not give the full flavor of its potential scope of activities. The language of the bill provides numerous opportunities for the Board and Director, if funded by Congress, to expand the scope of its programs in many directions. Essentially, the NTF would become a visible focal point for the civilian technology-support activities of the Federal government, other than those of NASA, DOE, and the regulatory agencies.

Interestingly, however, the NTF would be given few formal authorities that do not now exist someplace in the Federal Government. In this sense, it would not substantially expand Federal involvement in the private sector's innovative activities, except insofar as (1) it envisions implementation of certain Stevenson-Wydler Act authorities that are not currently being carried out, and (2) the aggregation of such activites in one independent agency that would have no concern other than the support of civilian technology would give the programs new focus and new impact. The bulk of its budget would be made up of transfers of budget authority from programs that are already funded at levels envisioned in the bill, while new programs would, at least in the initial years, receive relatively modest funding.

Because the NTF proposal is among the more comprehensive of those under consideration in this report, and because it has been widely discussed over the last several years, it provides a convenient base line with which to compare other proposals, as will be done in subsequent paragraphs.

H.R. 4361 The Advanced Technology Foundation Act

The purposes of the Advanced Technology Foundation Act are to:

> "...facilitate the movement of basic scientific concepts into commercial products or processes, and assist in the diffusion of new technology to industrial sectors to encourage the technological modernization of American industry."

The Act would accomplish these purposes by establishing a new independent Federal agency, the Advanced Technology Foundation, governed by a Board and a Director modeled after the structure of the National Science Foundation.

The National Science Foundation would be authorized by the bill to support education and training for scientists, engineers, and technicians in robotics and automated manufacturing, including funds for graduate, undergraduate, and post-doctoral assistance; equipment; and curriculum development.

Finally, the National Research Council of the National Academies of Science and Engineering would be directed to establish a National Robotics and Automated Manufacturing Systems Program Review Board to review all aspects of Federal involvement with robotics and automated manufacturing systems, report its finding, and make recommendations regarding such Federal involvement.

At a conceptual level, this bill represents a focusing of national efforts on one important area of industrial technology: robotics and automated manufacturing. It builds on existing authorities of the NSF and Department of Commerce, and its only new activities are the NBS Research Center and the NRC Board. From another perspective, this bill would do for robotics and automated manufacturing what the National Technology Foundation proposed in H.R. 481 would do for civilian industrial technology in general. The bill is also similar in concept and function to H.R. 4415/S. 1286, The Manufacturing Sciences and Technology R&D Act.

This bill would establish a substantial focused program in budgetary terms, with a first year authorization of $37.25 million, rising to $72.25 million in the eighth year.

H.R. 4415/S. 1286 The Manufacturing Sciences and Technology Research and Development Act

(Fuqua / Gorton, et al.)

(This discussion is based on the bills as introduced and does not reflect recent action on S. 1286 in the Senate Committee on Commerce, Science and Transportation.)

This Act is intended to "...establish a program for conducting research which will produce more efficient manufacturing technologies and for conducting research utilization activities to encourage widespread adoption of these technologies."

The Act would authorize the Office of the Assistant Secretary of Commerce for Productivity, Technology and Innovation (OPTI) to fund, through grants and cooperative agreements, basic and applied research on manufacturing technologies in universities, non-profit institutions, firms, industry associations, and other institutions. As part of this authority, OPTI could fund Centers for Manufacturing Research and Technology Utilization through consortia of research organizations, manufacturing industries or industry associations. The Act would also authorize the Secretary of Commerce to study how the utilization of advanced manufacturing technology can best be enhanced through the retraining of displaced workers, to study the technological competitiveness of selected industry sectors, and to establish a Manufacturing Sciences and Technology Enhancement Advisory Committee. It would authorize up to $20 million in the first year, rising to $67 million in the third and succeeding years, and is thus quite similar in cost to H.R. 4047, the robotics bill.

While it differs in certain details, this Act would specifically authorize OPTI to support R&D in manufacturing technologies using mechanisms that are quite similar to those already authorized but not funded under the Stevenson-Wydler Act. Similarly, its main R&D support provisions are of various technologies; the levels of R&D in the private sector, government, and other nations related to the technologies; and the competitive position of the technologies, and would develop and report to the President and the Congress on a technology development plan for each technology determined to be strategic. If this bill were adopted, the Academies would become more intensively involved in the competitive assessment of technologies than they have been in the past.

H.R. 2525 (to establish a) National Commission on Technological Innovation and Industrial Modernization

(Pashayan)

This bill would establish a National Commission on Technological Innovation and Industrial Modernization to:

> "...examine and evaluate all relevant Federal laws and policies...and ... submit to the President and the Congress...a national industrial strategy [which] shall be a comprehensive plan along with legislative recommendations to coordinate Federal laws and policies so as to assure the economic vitality and national security of the United States now and into the twenty-first century."

The 21-member commission would have members appointed by both the President and the Congress. It would be directed to include technology explicitly in its domain of concern. Since the commission is empowered only to do a study and then to go out of business, it would not take any actions itself. In this sense, the commission proposal is at the opposite extreme from the National Technology Foundation proposed under H.R. 481. Of course, it might make recommendations that would lead to substantial Federal actions by other agencies.

This commission would have a charter not unlike the one given to the President's Commission on Industrial Competitiveness appointed in 1983 by President Reagan, and would have a more limited charter than the National Academy committee called for under H.R. 1243/S.428.

Mr. LUNDINE. And now the subcommittee stands adjourned until 9:30 a.m., next Tuesday, June 12.

[Whereupon, at 11:15 a.m., the committee recessed, to reconvene at 9:30 a.m., Tuesday, June 12, 1984.]

FEDERAL ORGANIZATION FOR TECHNOLOGICAL INNOVATION

TUESDAY, JUNE 12, 1984

U.S. House of Representatives,
Committee on Science and Technology,
Subcommittee on Science, Research and Technology,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:35 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Present: Representatives Walgren, Brown, MacKay, Valentine, Gregg, Skeen, and Bateman.

Mr. MacKay [presiding]. Good morning. I will call to order this hearing.

This marks the second and concluding week of the Subcommittee's hearing on Federal Organization for Technological Innovation.

Today we continue our consideration of the several proposals to establish a Technology Foundation in the Federal Government as a sister agency to the National Science Foundation. In addition, we have also asked our witnesses to comment on the two bills which would initiate programs of research and development in the areas of manufacturing technology and robotics.

The health and vitality of American technology has made a major contribution to America's economic progress in the last 30 years, but our productivity growth has fallen off, and our international competitiveness has not allowed us to do as well as we should in the international marketplace. Our focus in these hearings is really on the question: What could and should the Federal Government do about this?

I announce with regret that one of our witnesses, Dr. Lewis Branscomb, the chief scientist of IBM and a former chairman of the National Science Board, has had to cancel his appearance. However, I am glad to announce the addition to our list of witnesses our colleague from Pennsylvania, Congressman Don Ritter.

Congressman Ritter is scheduled as the first witness. He is not present now, and so we will go ahead with Mr. Sydney L. Jones, Under Secretary for Economic Affairs to the U.S. Department of Commerce.

Mr. Jones, welcome to the committee.

STATEMENT OF SYDNEY L. JONES, UNDER SECRETARY FOR ECONOMIC AFFAIRS, U.S. DEPARTMENT OF COMMERCE, ACCOMPANIED BY EGILS MILBERGS, DEPUTY ASSISTANT SECRETARY FOR PRODUCTIVITY, TECHNOLOGY, AND INNOVATION

Mr. JONES. Thank you, Mr. Chairman and members of the subcommittee.

I appreciate the opportunity to appear before you to discuss the future role of the Federal Government in providing support and encouragement for technology development and industrial innovation, and particularly you requested our views on four bills which pertain to the Federal organizational structure in this area.

These bills have many positive objectives, but we do not agree with the procedures recommended to obtain those objectives. Accordingly, we do not support their enactment, for reasons I will briefly summarize.

These bills all have as their common objective the fostering of this Nation's technological base and our worldwide competitiveness.

H.R. 1243 and H.R. 2525 mandate studies of various aspects of our industrial base. H.R. 1243 requires the Office of Science and Technology Policy to conduct a study to identify technologies of economic and strategic importance to the Nation and to prepare plans for their development.

H.R. 2525 would establish a National Commission on Technological Innovation and Industrial Modernization with responsibility for the preparation of a national industrial strategy.

In contrast to the first two bills, H.R. 481 and 4361 would proceed to implement immediately new Federal programs to fund the development of new technologies. The first would establish a National Technology Foundation composed of several existing Federal agencies.

Among the many responsibilities of the foundation would be the operation of grant programs for the development of high technology small businesses. The latter bill would create the Advanced Technology Foundation to establish and support federally funded R&D programs.

The development and commercialization of new technologies is a high priority for this administration. Innovation process directly affects our international competitiveness. It is crucial to our economic well-being.

Without question, the issue of the competitive status of our products in the world markets depends heavily upon the creation of new technology and the providing of new products through the use of technology and productivity. Innovation and productivity are indeed the keys to offering attractive products at competitive prices.

Thus, while we strongly support the goals of the bills, we oppose their individual enactment, which is based on our belief that they would approach the issue in the wrong way. We share, however, with the sponsors of these bills, a deep concern that the health of the innovation process is strengthened and maintained in this country.

Each of these bills has as its premise the need for an industrial policy that will somehow guide our Nation's technological development. It is the view of this administration that we already have such a policy, which is to increase actual research, to improve the flow of information and technology transfer, to provide incentives both to create technology and to invest in it, and, most importantly, to remove the barriers to the development of technology.

President Reagan spoke to this point when he created the President's Commission on Industrial Competitiveness, which is an active group studying these issues. President Reagan's statement emphasizes that the governmental role should be oriented toward the removal of barriers, which would make innovation by the private sector more feasible.

Conversely, it rejects attempts at centralized planning of the kind envisioned by H.R. 1243 and H.R. 2525. President Reagan's view is especially applicable to advances in technology.

Government officials should not be placed in the position of emphasizing specific technologies, but, to the contrary, should emphasize the growth of innovation and technology in general.

Government officials do not have adequate access to the marketplace ideas or the information necessary to make such decisions. These objectives apply equally to H.R. 481 and H.R. 4361, which go a step beyond the development of plans to the funding of actual research projects based upon such assessments.

The administration has sought to carry out the role it deems appropriate through a variety of actions. We have moved to strengthen the country's research and development by increasing R&D spending. In the fiscal year 1985 budget, Federal funding of the R&D increase is 14 percent, to $53 billion. This increase is on top of a 17-percent increase in fiscal year 1984.

Enactment of the incremental tax credit for research and experimental expenditures in 1981 was another important innovation. The tax cuts contained in the Economic Recovery Tax Act of 1981 have laid the overall groundwork for stable economic growth which has rebounded at a very strong rate and created the necessary environment for general innovation and economic investment.

In addition, the administration has made a number of proposals that are now awaiting action by the Congress. The National Productivity and Innovation Act, for example, would encourage procompetitive R&D joint ventures by reducing possible antitrust liability from treble to actual damages.

Further, the administration endorses legislation to change the Federal policies governing the allocation of patent rights to inventions under Federal grants, contracts, and cooperative agreements in order to enhance the possibility of commercialization of the large government portfolio of inventions. This idea is currently being considered by your subcommittee, and we look forward to continuing to work with you on this subject.

The administration's general opposition to an industrial policy approach to innovation is based on the belief that certain types of Government programs are neither appropriate nor effective.

The startup of new, large-scale programs to fund targeted research in various industries through Federal grants constitutes, in our mind, intervention in the marketplace forces. The product of such programs seldom match what the market demands, and the programs would represent yet another drain on the Federal budget.

In addition to the bills I have already discussed, I would express similar concerns about two other bills now being considered by your subcommittee. H.R. 4047 and H.R. 4415 both envision large-scale grant programs, the latter, for example, costing over a quarter of a billion dollars over the next 5 years if enacted.

Once again, we strongly support the goals of innovation and technological development, but we have serious reservations about the efficacy of this approach.

In conclusion then, let me emphasize that we support strongly the innovation process. We believe we have a strong program comprised of increased R&D spending, the development of increased information and transfer of technology, the creation of incentives, and the removal of barriers, but we do not support the bills under consideration.

Finally, Mr. Chairman, I'm accompanied today by Egils Milbergs, who is Deputy Assistant Secretary for Productivity, Technology, and Innovation in the Department of Commerce. He is an acknowledged expert in this area and will help me answer whatever questions you might have.

[The prepared statement of Mr. Jones follows:]

STATEMENT OF
SIDNEY L. JONES
UNDER SECRETARY OF COMMERCE
FOR ECONOMIC AFFAIRS
BEFORE THE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
OF THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

JUNE 12, 1984

FEDERAL GOVERNMENT SUPPORT OF TECHNOLOGY DEVELOPMENT AND INDUSTRIAL INNOVATION

Mr. Chairman and members of the Subcommittee, I appreciate this opportunity to appear before you to discuss the present and future role of the Federal government in providing support and encouragement for technology development and industrial innovation. In particular, you requested my views on four bills which pertain to Federal organizational structure in this area, including H.R. 481, 1243, 2525 and 4361. Although each of these bills has laudable objectives, the bills also contain questionable means to obtain these objectives. Accordingly, we do not support their enactment for reasons I will discuss below.

These bills all have as their common objective the fostering of this nation's technological base, and hence, our worldwide competitiveness. H.R. 1243 and H.R. 2525, mandate studies of various aspects of our industrial base. H.R. 1243 requires the Office of Science and Technology Policy to conduct a study to identify technologies of economic and strategic importance to the nation and to prepare plans for their development. H.R. 2525 would establish a National Commission on Technological Innovation and Industrial Modernization with responsibility for the preparation of a national industrial strategy. This strategy would include provision for the development of new technologies.

In contrast to the first two bills, H.R. 481 and 4361 would proceed to implement immediately new Federal programs to fund the development of new technologies. H.R. 481 would establish a National Technology Foundation, composed of several existing Federal agencies including the Patent and Trademark Office, the National Bureau of Standards and others. Among the many responsibilities of the Foundation would be the operation of grant programs for the development of high technology small businesses. H.R. 4361 would create the Advanced Technology Foundation to establish and support Federally funded R&D programs. The cost of H.R. 4361 would be $500 million over the first four years.

The development and commercialization of new technologies is a high priority for this Administration. The innovation process directly affects our international competitiveness. It is crucial to our economic well-being. Without question the competitiveness of our products in world markets depends in large measure upon our ability to take advantage of new technology to offer new products, and upon the use of that technology to improve our productivity. Innovation and productivity are the keys to offering attractive products at competitive prices in world markets.

Thus, while we oppose the enactment of these particular bills, our opposition is based solely upon the particular means that they propose to use to meet the objective of supporting and enhancing industrial innovation. We share with the sponsors of these bills a deep concern that the health of the innovation process be maintained in this country.

Each of these bills has as its premise the need for an industrial policy that will guide our nation's technological development. It is the view of this Administration that such a policy is simply impractical to implement. President Reagan made this point in his statement last year announcing the appointment of the members of the President's Commission on Industrial Competitiveness. He said,

> Some believe that the government should try to read trends to determine which products, services and industries have a place in our future, and which do not. They would have government planners divert resources away from traditional industries and channel them into new fields. But the history of progress in America proves that millions of individuals making decisions in their own legitimate self-interest cannot be outperformed by any bureaucratic planners.
>
> Government's legitimate role is not to dictate detailed plans, or solutions to problems for particular companies or industries. No, government serves us best by protecting and maintaining the marketplace, by ensuring that the rules of free and fair trade, both at home and abroad, are properly observed, and by safeguarding the freedoms of individual participants.

President Reagan's statement describes a governmental role that is oriented to the removal of barriers which would make innovation by the private sector more difficult. Conversely, it rejects attempts at centralized planning of the kind envisioned by H.R. 1243 and H.R. 2525. President Reagan's view is especially applicable to advances in technology. Government officials should not be placed in the position of picking technology winners and losers, because, regardless of their expertise, they do not have as much access as the entire marketplace to rich and diverse information about the factors determining the success or failure of innovations. These objections apply equally to H.R. 481 and H.R. 4361, which go a step beyond the development of plans to the funding of actual research projects based upon such assessments.

The Administration has sought to carry out the role it deems appropriate through a variety of actions. We have already moved to strengthen this country's research and development by proposing in the FY 1985 budget an increase in Federal funding of R&D of 14 percent, to $53 billion. This increase is on top of a 17 percent increase in FY 1984. The enactment of the incremental tax credit for research and experimental expenditures in 1981 is encouraging innovation. The tax cuts also contained in the Economic Recovery Tax Act of 1981 have laid the groundwork for stable economic growth, and for the necessary environment for innovation to flourish. In addition, the Administration has made a number of proposals that are now awaiting action by the Congress. The National Productivity and Innovation Act, for example, would encourage pro-competitive R&D joint ventures by reducing possible antitrust liability from treble to actual damages. Further, the Administration endorses legislation to change in the Federal policies governing allocation of patent rights to inventions under Federal grants, contracts and cooperative agreements, to enhance the possibility of commercialization of the large government portfolio of inventions. This idea is currently being considered by your subcommittee and we look forward to continuing to work with you on this subject.

The Administration's opposition to an industrial policy approach to innovation is based on the premise that certain types of government programs are neither appropriate nor effective. The start-up of new large scale programs to fund "targeted" research in various industries through Federal grants constitutes intervention in the market place. The product of such programs seldom match what the market demands. And, of course, the programs would represent yet another, and from past experience perhaps permanent, drain on the Federal budget.

In addition to the bills I have already discussed, I would express similar concerns about two other bills now being considered by this subcommittee. H.R. 4047 and H.R. 4415 both envision large scale grant programs, the latter, for example, costing over a quarter of a billion dollars over five years if enacted. Again, we have no quarrel with their intent, but we have serious reservations about the efficacy of their approach.

In closing, let me repeat my conviction that the innovation process in the United States is of crucial importance for our economic well-being. We believe the Administration is pursuing policies and measures to keep innovation strong in the United States. We do not believe the bills before this Committee will advance us toward our commonly held goal.

I am prepared to answer any questions.

BIOGRAPHY

SIDNEY L. JONES
UNDER SECRETARY FOR ECONOMIC AFFAIRS
DEPARTMENT OF COMMERCE

Sidney L. Jones was nominated to be Under Secretary of Commerce for Economic Affairs by President Reagan on January 23, 1984.

Dr. Jones, 50, has held several ranking positions in Washington over the past 15 years, including presidential appointments in previous Republican administrations at the White House, Commerce, and Treasury.

The Under Secretary for Economic Affairs is the chief economic adviser to the Secretary and directs the department's major programs of data collection, analysis, and policy appraisal in the fields of economics and demographics. The Under Secretary exercises policy direction and supervision over the analysis of economic conditions and policy; stimulation of productivity, growth, technology and innovation; and over the Bureau of Economic Analysis and the Bureau of the Census.

Dr. Jones was resident scholar at the American Enterprise Institute. He also was professorial lecturer at Georgetown University and Visiting Professor at Dartmouth College.

He first joined the Commerce Department in 1973 as Assistant Secretary for Economic Affairs and was named Deputy Assistant to the President and Deputy to the Counselor for Economic Policy to the President in 1974. From 1975 to 1977 he was Assistant Secretary of the Treasury for Economic Policy. He has also served as Minister-Counselor for Economic Affairs to NATO, Special Assistant to the Chairman of the President's Council of Economic Advisers, and Assistant to the Federal Reserve Board.

A native of Utah, Jones graduated from Utah State University and received masters and Ph.D. degrees from Stanford University. He was Professor of Finance at the University of Michigan and Associate Professor at Northwestern University.

Dr. Jones and his wife, Marlene, reside in Potomac, Maryland; they have five children.

March 1984

Mr. MacKay. Thank you, Mr. Jones. I might ask a question or two.

There was recently an editorial in Science magazine in which the author said that what's really happening is not an overall advance in research and development in America, but that in the last four years what's really happening is a massive increase in military R&D coupled with a decrease in civilian R&D, and he expressed the concern that at the time we are doing this, which reflects an effort to compete in the military arena with the Soviets with which we do not disagree, we are basically pulling away from competition with the Japanese, the Germans, and others in the competition for civilian markets, and the editorial suggested that we're going to pay a price for that, that there's no free lunch, and that the price is going to be, at some point in the future, a loss of market share competitiveness.

The point finally made by the writer of the editorial was not that we should get into a battle between civilian and military, although he said the reason for not getting in that is we already know we'll lose that. He simply said we should become a point of advocacy for civilian research and development so that the advance in the military R&D effort does not come at the expense of civilian R&D.

Do you agree with those conclusions?

Mr. Jones. I think you have phrased it very well, that the increase in military defense has been a necessary part of our national and international priorities.

At the same time, it is still significant that private research is still more than half of our total research over the Federal part, and indeed the private R&D went up 11 percent in 1984. So we are not declining in any way. Indeed, we are accelerating.

In reality, we still comprise in basic research the equivalent of Japan, the Federal Republic of Germany, France, and the United Kingdom combined, or we spend three times as much on basic research as any other nation.

I would certainly agree that our goal should be to implement private research, and that is the point of our efforts which I have described, to both increase the Federal level basic research, which is somewhat generic—it can be used in diverse ways—at the same time trying to stimulate the private sector by removing the barriers of the antitrust concerns about the joint operation of research, by removing the concerns about incentives, by providing the tax incentives, the issue of the 861 tax code, and, finally, by the process, which is the main thrust of our Department of Commerce program.

So I would certainly agree with the interpretation you have placed on that article.

Mr. MacKay. All right. I would like to ask just one other question, and that is, is the position of the Reagan administration regarding continued support for aeronautical research consistent with what you said about, "We should not be in the business of Government trying to target industries?"

Mr. Jones. Aeronautical research, of course, is closely linked to our military capacity, although it spreads into NASA also. I think the emphasis there is to compare ourselves both for the peacetime and the military application of the research, one which you could not expect, at this time at least, a private company to undertake by itself.

Mr. **MacKay**. All right. Mr. Skeen, do you have any questions?

Mr. **Skeen**. I have no questions, Mr. Chairman. Thank you

Mr. **MacKay**. Mr. Brown.

Mr. **Brown**. Mr. Jones, I apologize for having stepped out for a moment, and I haven't completely digested all of your testimony, but I am trying to understand a little bit better the posture of the administration on this matter of facilitating the development of technology.

Taking specifically the Technology Foundation bill, which, as you know, has been before this committee for a number of years, we have been really trying to treat it as a matter of focusing largely existing efforts in a more effective way within the administration.

If we were to succeed in doing that, it would seem to me that such an approach would be consistent with the philosophy of the administration; would it not?

Mr. **Jones**. Yes, sir. The Department of Commerce, as you well know, has a very specific proposal before the Congress to create a Department of International Trade and Development, and, as part of that reorganization, would create an under secretary for the technology and science areas. It would gather together many of those disciplines.

Mr. **Brown**. Didn't it actually include at one point, and I'm not, I confess, really up to date right now, an administration within that department for innovation and productivity?

Mr. **Jones**. Yes, sir. It would be an under secretary who would combine the Patents, the National Bureau of Standards, my particular activities in the Office of Technology and Innovation and Productivity, and would give it, we believe in the Department of Commerce, a better focus and a higher visibility.

Mr. **Brown**. Well, that's essentially what we were seeking to do here, but without going to the whole extent of revising the whole Department of Commerce, which we didn't feel was our prerogative in this committee, and I'm not sure you're going to get away with it either. But you would not see anything that contradicts your basic philosophy in seeking to achieve increased productivity within the existing bureaucracy, would you?

Mr. **Jones**. We are always, of course, trying to organize for better cooperation. That in a generic sense is certainly feasible.

My concern would be those aspects of the bills which would attempt to target specific technologies, and I frankly would have to admit great concern about the spending levels.

I've spent the last several days trying to adjust to a 4-percent, across-the-board reduction in our various authorizing budget legislation, and I'm frankly under considerable duress to organize properly the things that we are already doing.

I welcome that across-the-board approach, and indeed I think in the second tier fiscal policies which confront the Nation in coming years, we're going to have to consider almost everything.

So I would be concerned somewhat with the approach in case it would become a camel's nose under the tent with regard to industrial policy, and, frankly, I would be very concerned about the levels of appropriations.

Mr. **Brown**. Well, we all have to use good judgment in doing these things as to the level of spending. I know of no one who doesn't feel we wouldn't help our economy more by balancing the budget than almost anything else that we did.

On the other hand, when this administration came in, they thought we were spending too much money on science and engineering education, and then they decided that we weren't spending enough.

So it's a matter of judgment, to some degree, as to what the proper level of expenditure for some of these programs might be as you perceive their relevance to our national priorities a little more clearly.

Am I making a statement you can agree with, or not?

Mr. **Jones**. Oh, I think yes, we would have to rely on the Congress to use great discretion. Funding the levels of $57 or $250 million per year with regard to the activities we are already undertaking would really be very major, far beyond anything that we would have in mind.

Mr. **Brown**. Well, confronting the possibility that we might have to live with your administration for another 4 years, I'm really trying to find out how we can work most effectively with you, and that's the purpose of my questioning.

Thank you, Mr. Chairman.

Mr. **MacKay**. Mr. Jones, thank you very much.

Mr. **Jones**. Thank you, sir.

Mr. **MacKay**. Our next witness will be Congressman Don Ritter. I understand that your time is very tight. We will accept your statement in the record, without objection, and any summary remarks you would care to make.

STATEMENT OF HON. DON RITTER, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF PENNSYLVANIA AND VICE CHAIRMAN, TASK FORCE ON HIGH TECHNOLOGY INITIATIVES, HOUSE REPUBLICAN RESEARCH COMMITTEE

Mr. **Ritter**. Thank you, Mr. Chairman.

It kind of depends as to what Energy and Commerce is doing down on the first floor—subjects of interest to technological innovation like patent term restoration, like the Superfund, and manifold billions of dollars that are on the same order of magnitude of the entire research and development budget of the industry. So I think my presence will be required there, but there is somebody there watching to see what's happening.

I'd like to thank you for the opportunity to testify before the subcommittee today on the Federal role in technological innovation.

As vice chairman of a 140-member Republican task force on high technology initiatives, as a former university engineering professor and research administrator who experienced firsthand the sponsored research activities at universities—these are largely Federal, but some State and local—the public research support, and the private-sponsored research, I'm grateful to be able to share some views with you.

Everybody accepts the fact that our Nation's industrial competitiveness and ability to create new jobs depend on the evolution and application of new technology.

A strong technological base is important to strengthen our economy, to enhance opportunity, and we need to remember that while there are additional steps that we can take to improve our position in world markets, we have done many things right.

At the recent economic summit in London, European leaders acknowledged the impressive gains in new job creation in the United States. They expressed surprise at the positive results that have stemmed from lesser amounts of Government intervention and regulation and greater dependence on private sector investment in the economy. We just may be moving in the right direction.

But there are certain steps that we can take to keep the jobs that we have and to create new jobs. From Mitterrand to MIDI, there seems to be a growing consensus that the kind of decentralized creative forces that have characterized some of the newer industries in the United States are the model for the future, not more central foci.

As the gentleman from California mentioned, everybody agrees that a balanced budget would allow credit to be available and would enhance innovation, investment and productivity.

But, you know, coming back to that, we can't avoid the fact that we are trying to narrow budget deficits and that the creation of wholly new programs or wholly new agencies does put an additional strain, and in this climate it is difficult to gain the support to create this kind of agency.

Not only that, the track record of the Federal Government in technology, applied technology dimensions to our economy, has not been something we can stand up and crow about. The Department of Energy is a prime example, where the battle for the money became fundamentally political.

We can, and we must, administer the Federal research efforts to get a bigger bang for our buck. Well, what does that mean? It means that in NSF, for example, we can and we are set up to develop some balances between the basic research, and with some additional resources developing an engineering research and an engineering technology arm based on peer review, limiting the political inputs into the system.

We can also pursue Federal technology programs that will provide more research benefits to the products, the markets, and the competitive positions of firms in the private sector.

How can we do that? Well, we need to give leadership to the private sector. As long as the Federal Government is looked upon by the research establishment in the nonprofits, which includes universities and research institutes, as the rich uncle, the unique capabilities of these nonprofits, these universities and research institutes, will not in large measure be motivated by the need for industrial competitiveness; it will be motivated by the Federal R&D economy; the two can merge, but we have to be careful as to who is the tail and who is the dog. It would be preferable to have the private sector motivations become the dog and the Federal capabilities the tail.

One way to achieve a greater motivation coming through the private sector innovation area is to provide greater Federal incentives for university, industry, and cooperative projects that are important to the private sector, as judged by its financial support for these kinds of projects.

The level of the research and development tax credit as it applied to joint work between private firms or consortia of firms if it was increased, could funnel new resources into the universities, encouraging more market-oriented research and development.

That is a way to go directly between these marvelous institutions of research and development and the subject that we're really all concerned with—that is, industrial competitiveness and the private sector that is responsible for that competitiveness. This is not to supplant basic research at universities; it is to complement that research.

Right now, on the order of only 5 to 10 percent of most university research budgets are derived from private sector sponsorship. No wonder industrial competitiveness and products, markets, invention, and innovation has an eventual buyer in the world market scheme is not the motivating force.

Encouraging greater university involvement in industrial research will have many long-term benefits.

John Young, who testified last week, chairman of Hewlett-Packard, and the chairman of the President's Commission on Industrial Competitiveness, noted that there's a shortage of engineers graduating at the master's and doctoral levels, and this is the pool where the teachers of the future must come from to meet the current shortage of engineering faculty.

A more cooperative approach between industry, universities, and government could bring engineering faculty to the cutting edge of research, using the latest research equipment while training students.

How do we get there? Where does the motivation come from? Does it come from a flood of new Federal funds, or do we stimulate the private sector to get more directly involved?

I think the latter is going to have more impact on industrial competitiveness. It's going to cost, but it may be a more direct route to the goal that we share.

In terms of the answer to stimulating greater private sector involvement, I'm not sure that it's a new Federal agency that deals specifically, and is reorganized specifically, for advanced technology or more studies.

Again, I think that we maybe set up within the National Science Foundation to accommodate some of that at least, but perhaps it's in a different utilization of our research resources whereby agencies provide greater priority to projects at universities which have strong support from industry.

If we are going to expand the Federal involvement in the search for an enhanced industrial competitiveness without sacrificing basic research commitments, we need to pay closer attention to these market trends, products, processes, et cetera, and that only comes, again, I mentioned, where the private sector is the dog and the Government the tail, not vice versa.

You know, if greater private sector application of advanced technology is being pushed and pursued, and we are looking for the Federal Government to go along with this, the National Bureau of Standards has already shown a very good track record in achieving this goal, and the specific area I'm familiar with, as a metallurgist—they have brought together cooperative ventures among private firms to bring high technology to welding, laser sensors, to steel ingot solidification, and advanced nondestructive materials testing. Well, let's stimulate further cooperative ventures of that type.

Another way to achieve this goal is to provide support from existing Federal laboratory activities for cooperative laboratory-industry projects.

Federal laboratory research amounts to some $17 billion a year. Much of it is dedicated, but some of that can be focused and targeted on the problems of American industry, where private sector cooperative, joint R&D ventures can be the dog coming in and wagging some of that extremely capable tail.

Jay Keyworth, the President's science adviser, has spearheaded an initiative involving researchers in the steel industry, the Federal labs, and the universities. I am personally involved in that, and I sense that this could be a model for further programs of this kind.

The effort is in the planning stages at this time, and representatives from the steel industry, the Government, and the university are currently setting research priorities to try for leapfrog steelmaking technology. This leapfrog technology is aimed at giving our basic manufacturing industry a major advance in steelmaking productivity and could help the industry gain a competitive edge over its global competitors.

The possibility exists in a number of other basic manufacturing areas as well.

Now these are some concrete examples of how the Federal Government has entered into the realm of private sector industrial competitiveness and where they have been, to this point, successful, and we can develop additional programs of this type.

We can modify our efforts at the Federal level, existing multibillion-dollar efforts, to promote innovation and industrial competitiveness without necessarily building new agencies or sponsoring new studies which parallel past or existing productivity commissions.

One of the bills before us sounds very similar to the Baruch Commission under Carter and the Young Commission under Reagan, respectively.

Now if there is a specific gap in Federal support, or research support, or training, that could well be another story.

One of the bills before us, manufacturing sciences and technology—H.R. 4415 and S. 1286 take some steps in a specific direction where we seem to have agreement that greater emphasis is necessary.

But I might add that one of the reasons that manufacturing sciences and technology is not pursued in our universities and our research establishments to the level and to the extent that you would think it would be, that it should be, is that many of these establishments have been part and parcel of a Federal R&D economy which, for 25 years, did not focus on manufacturing, it wasn't the sexy field, and we have lost out in that regard.

We could have done better.

We have done better in manufacturing technology than the conventional wisdom assumes, but there are vast gaps where competitors have really taken over the leadership in the world markets.

I've tried to give some concrete examples in commenting on the bill before us where Government's role can be made more effective. However, in closing, I would like to second my colleague from California, Ed Zschau's remarks of last week.

In our Republican House Task Force on High Technology Initiatives, we have taken pains to focus on the process of innovation, targeting the process, if you will, as the key to competitiveness and economic growth.

I know there's dichotomies between committees, and certain committees have certain jurisdictions, and we have bemoaned this fact, but we really do need to focus on what we in the science community would call the first order effects, and that most certainly is the process.

We feel that the basic features of our competitive landscape are set by incentives for innovation and invention, incentives, risk-taking, incentives for performing market-oriented research and development, and I won't repeat Representative Zschau's excellent testimony, but I will quote just one quote from our Senate colleague, Paul Tsongas, when he stated,

> Because I am a Democrat, I consider the ethic in the House among my fellow colleagues that this was pro-business, and therefore we are against it. The bill, which I did not support, did more for the economy of my State than anything I did as a Congressmen.

I do not wish to make this any kind of partisan statement, because there's certainly enough blame to go around in a bipartisan way, but I must say that Tsongas hits a nail on the head. He is talking about the reduction in the maximum tax on capital gains. Speaking of blame to go around, it was President Nixon who upped that tax to 49 percent, but President Carter who opposed its coming down to 28. Senator Tsongas stated that "it did more for the economy of my State Massachusetts than anything that I did as a Congressman."

That reduction caused venture capital to rise from a low of $50 million, the order of magnitude of the agency budgets that we're describing within these bills, to some $4 billion, today's amount.

The tax reductions are a good example of a first order effect. Dare we to think what would happen to the tax shelter industry if we extended some of the so-called tax-free status to investment in industrial America and the venture capital pool? We're talking the difference between $50 million, $4 billion, and on the order of the $100–$200 billion.

Thank you, Mr. Chairman. I appreciate the opportunity to testify.

[The prepared statement of Mr. Ritter follows:]

STATEMENT BY CONGRESSMAN DON RITTER
BEFORE THE
HOUSE SUBCOMMITTEE ON SCIENCE RESEARCH AND TECHNOLOGY
JUNE 12, 1984

MR. CHAIRMAN:

I WANT TO THANK YOU FOR THIS OPPORTUNITY TO TESTIFY BEFORE THE SUBCOMMITTEE TODAY ON THE FEDERAL ROLE FOR TECHNOLOGICAL INNOVATION.

AS VICE-CHAIRMAN OF THE 140 MEMBER REPUBLICAN TASK FORCE ON HIGH TECHNOLOGY INITIATIVES, AND AS A FORMER UNIVERSITY PROFESSOR AND RESEARCH ADMINISTRATOR WHO EXPERIENCED FIRST HAND PUBLIC (LARGELY FEDERAL BUT SOME STATE AND LOCAL) AND PRIVATE SPONSORED RESEARCH, I WOULD LIKE TO SHARE SOME VIEWS WITH YOU. OUR NATION'S INDUSTRIAL COMPETITIVENESS AND ABILITY TO CREATE NEW JOBS DEPEND ON THE EVOLUTION AND APPLICATION OF NEW TECHNOLOGY. I COMMEND THE CHAIRMAN FOR HIS INTEREST AND LEADERSHIP IN THIS AREA AND FOR SPONSORING THESE HEARINGS. I HAVE HAD THE PERSONAL PLEASURE OF WORKING WITH THE CHAIRMAN ON A VARIETY OF SCIENCE BASED ISSUES.

A STRONG TECHNOLOGICAL BASE IS IMPORTANT TO STRENGTHEN OUR ECONOMY AND ENHANCE OPPORTUNITY. WE NEED TO REMEMBER THAT WHILE THERE ARE ADDITIONAL STEPS THAT WE CAN TAKE TO IMPROVE OUR POSITION IN WORLD MARKETS, WE HAVE DONE MANY THINGS RIGHT. AT THE RECENT ECONOMIC SUMMIT IN LONDON, EUROPEAN LEADERS ACKNOWLEDGED THE IMPRESSIVE GAINS IN NEW JOB CREATION IN THE UNITED STATES. THEY EXPRESSED SURPRISE AT THE POSITIVE RESULTS THAT HAVE STEMMED FROM LESSER AMOUNTS OF GOVERNMENT INTERVENTION AND GREATER DEPENDENCE ON PRIVATE INVESTMENT IN THE ECONOMY. WE SEEM TO BE MOVING IN THE RIGHT

DIRECTION BUT CERTAIN STEPS ARE NECESSARY TO KEEP THE JOBS WE HAVE AND CREATE NEW JOBS.

THE MOST OBVIOUS FACTOR THAT LOOMS AS A THREAT TO SUSTAINING THE RECOVERY IS A FEDERAL DEFICIT SQUEEZING CREDIT. CLEARLY, WE MUST BRING IT UNDER CONTROL BEFORE IT CONTROLS US. IN THIS CLIMATE, IT'S DIFFICULT TO BUILD NEW FEDERAL AGENCIES WITH NEW BUDGETS AND NOT ONLY THAT, TECHNOLOGY ORIENTED FEDERAL AGENCIES HAVE NOT BEEN EMINENTLY SUCCESSFUL. AN EXAMPLE OF THIS IS THE DEPARTMENT OF ENERGY. WE MUST ADMINISTER FEDERAL RESEARCH AND DEVELOPMENT IN A MANNER THAT WILL RESULT IN A "BIGGER BANG FOR OUR BUCK," SO AS TO BETTER SUPPORT INDUSTRY'S EFFORTS TO APPLY OUR FEDERAL RESEARCH IN THE MARKETPLACE.

HOW CAN WE PURSUE FEDERAL TECHNOLOGY PROGRAMS THAT WILL PROVIDE MORE RESEARCH BENEFITS TO THE PRODUCTS, MARKETS AND COMPETITIVE POSITION OF FIRMS IN THE PRIVATE SECTOR? WE MUST GIVE LEADERSHIP TO THAT PRIVATE SECTOR. AS LONG AS THE FEDERAL GOVERNMENT IS LOOKED UPON AS THE RICH UNCLE BY NON-PROFIT RESEARCH ESTABLISHMENTS, THEIR UNIQUE CAPABILITIES WILL NOT IN LARGE MEASURE BE MOTIVATED BY THE NEED FOR INDUSTRIAL COMPETITIVENESS.

ONE WAY TO ACHIEVE THIS GOAL IS TO PROVIDE GREATER FEDERAL INCENTIVES FOR INDUSTRY/UNIVERSITY COOPERATIVE PROJECTS THAT ARE IMPORTANT TO THE PRIVATE SECTOR AS JUDGED BY ITS FINANCIAL SUPPORT FOR SUCH PROJECTS. THE LEVEL OF THE RESEARCH AND DEVELOPMENT TAX CREDIT AS IT APPLIES TO JOINT WORK BETWEEN PRIVATE FIRMS OR CONSORTIA OF FIRMS WILL FUNNEL NEW RESOURCES INTO UNIVERSITIES ENCOURAGING MORE MARKET-ORIENTED RESEARCH AND DEVELOPMENT.

THIS IS NOT TO SUPPLANT BASIC RESEARCH AT UNIVERSITIES. ON THE ORDER OF ONLY 5% TO 10% OF MOST UNIVERSITY RESEARCH BUDGETS NOW DERIVE FROM PRIVATE SECTOR SPONSORSHIP.

ENCOURAGING GREATER UNIVERSITY INVOLVEMENT IN INDUSTRIAL RESEARCH WILL HAVE MANY LONG TERM BENEFITS. JOHN YOUNG, CHAIRMAN OF HEWLITT-PACKARD, NOTED LAST WEEK THAT THERE IS A SHORTAGE OF ENGINEERS GRADUATING AT THE MASTER AND DOCTORAL LEVELS. THIS IS THE POOL FROM WHERE OUR TEACHERS OF THE FUTURE MUST COME TO MEET THE CURRENT SHORTAGE OF ENGINEERING FACULTY. A MORE COOPERATIVE APPROACH BETWEEN INDUSTRY, UNIVERSITIES AND GOVERNMENT COULD BRING ENGINEERING FACULTY TO THE CUTTING EDGE OF RESEARCH USING THE LATEST RESEARCH EQUIPMENT WHILE TRAINING STUDENTS.

HOW CAN WE ENCOURAGE THIS COOPERATION AND GREATER PRIVATE SECTOR INVOLVEMENT? I AM NOT SURE THAT THE ANSWER IS A NEW FEDERAL AGENCY FOR ADVANCED TECHNOLOGY OR IN MORE STUDIES. PERHAPS IT'S A DIFFERENT UTILIZATION WHEREBY AGENCIES PROVIDE GREATER PRIORITY TO PROJECTS AT UNIVERSITIES WHICH HAVE STRONG SUPPORT FROM INDUSTRY. AGAIN, IF WE ARE TO EXPAND FEDERAL INVOLVEMENT IN THE SEARCH FOR ENHANCED INDUSTRIAL COMPETITIVENESS -- WITHOUT SACRIFICING BASIC RESEARCH COMMITMENTS -- WE NEED TO PAY CLOSER ATTENTION TO MARKET TRENDS, PRODUCTS, PROCESSES ETC... THAT ONLY COMES WHERE THE PRIVATE SECTOR IS THE DOG AND THE GOVERNMENT THE TAIL... NOT VICE VERSA.

IF GREATER PRIVATE SECTOR APPLICATION OF ADVANCED TECHNOLOGY IS BEING PUSHED, THE NATIONAL BUREAU OF STANDARDS ALREADY HAS SHOWN A GOOD TRACK

RECORD IN ACHIEVING THIS GOAL. FOR EXAMPLE, IN A SPECIFIC AREA I'M FAMILIAR WITH AS A METALLURGIST, THEY'VE BROUGHT TOGETHER COOPERATIVE VENTURES AMONG PRIVATE FIRMS TO BRING HIGH-TECH TO WELDING; LASER SENSORS TO STEEL INGOT SOLIDIFICATION AND ADVANCED NON-DESTRUCTIVE MATERIALS TESTING.

ANOTHER WAY TO ACHIEVE THIS GOAL IS TO PROVIDE SUPPORT FROM EXISTING FEDERAL LABORATORY ACTIVITIES FOR COOPERATIVE LAB/INDUSTRY PROJECTS. FEDERAL LAB RESEARCH AMOUNTS TO SOME $17 BILLION PER YEAR. JAY KEYWORTH, THE PRESIDENT'S SCIENCE ADVISOR, HAS SPEARHEADED AN INITIATIVE INVOLVING RESEARCHERS IN THE STEEL INDUSTRY, FEDERAL LABS AND UNIVERSITIES. THIS EFFORT IS IN THE PLANNING STAGES AT THIS TIME AND REPRESENTATIVES FROM THE STEEL INDUSTRY, GOVERNMENT AND UNIVERSITIES ARE CURRENTLY SETTING RESEARCH PRIORITIES TO DEVELOP "LEAPFROG" STEELMAKING TECHNOLOGY. THIS "LEAPFROG" TECHNOLOGY IS AIMED AT MAKING A MAJOR ADVANCE IN STEELMAKING PRODUCTIVITY AND COULD HELP THE INDUSTRY GAIN A COMPETITIVE EDGE OVER ITS GLOBAL COMPETITORS. THE POSSIBILITY EXISTS IN OTHER AREAS AS WELL.

THESE ARE SOME CONCRETE EXAMPLES OF HOW FEDERAL PROGRAMS CAN BE EASILY MODIFIED TO PROMOTE INNOVATION AND INDUSTRIAL COMPETITIVENESS WITHOUT NECESSARILY BUILDING NEW AGENCIES OR SPONSORING NEW STUDIES WHICH PARALLEL PAST OR EXISTING "PRODUCTIVITY COMMISSIONS," BARUCH UNDER CARTER AND YOUNG UNDER REAGAN RESPECTIVELY. IF THERE IS A SPECIFIC GAP IN FEDERAL RESEARCH SUPPORT OR TRAINING, THAT COULD WELL BE ANOTHER STORY. MANUFACTURING SCIENCES AND TECHNOLOGY MAY BE SUCH AN AREA WHERE GREATER EMPHASIS IS NECESSARY. HR 4415 AND S. 1286 TAKES SOME STEPS IN THIS SPECIFIC DIRECTION.

IN COMMENTING ON THE BILLS BEFORE US, I'VE TRIED TO GIVE SOME CONCRETE EXAMPLES WHERE GOVERNMENT'S ROLE CAN BE MADE MORE EFFECTIVE. HOWEVER, IN CLOSING, I'D LIKE TO SECOND MY COLLEAGUE FROM CALIFORNIA, ED ZSCHAU'S REMARKS OF LAST WEEK. IN OUR HOUSE REPUBLICAN TASK FORCE ON HIGH TECHNOLOGY INITIATIVES, WE'VE FOCUSED ON THE PROCESS OF INNOVATION... TARGETING THE PROCESS, IF YOU WILL, AS THE KEY TO COMPETITIVENESS AND ECONOMIC GROWTH. WE FEEL THAT THE BASIC FEATURES OF OUR COMPETITIVE LANDSCAPE ARE SET BY INCENTIVES FOR INNOVATION AND INVENTION; FOR RISK TAKING; FOR PERFORMING RESEARCH AND DEVELOPMENT AND FOR EXPANDING ONE'S MARKETS. I WON'T REPEAT REPRESENTATIVE ZSCHAU'S EXCELLENT TESTIMONY. I'LL JUST QUOTE OUR SENATE COLLEAGUE PAUL TSONGAS WHEN HE STATED, "BECAUSE I AM A DEMOCRAT I CONSIDERED THE ETHIC IN THE HOUSE AMONG MY FELLOW COLLEAGUES THAT THIS WAS PRO-BUSINESS AND THEREFORE WE ARE AGAINST IT. THAT BILL WHICH I DID NOT SUPPORT, DID MORE FOR THE ECONOMY OF MY STATE THAN ANYTHING I DID AS A CONGRESSMAN."

THAT REDUCTION CAUSED VENTURE CAPITAL TO RISE FROM A LOW OF $50 MILLION, THE ORDER OF MAGNITUDE OF THE AGENCY BUDGETS WE'RE DESCRIBING WITHIN THESE BILLS, TO SOME $4 BILLION, TODAY'S AMOUNT. THE TAX REDUCTIONS ARE A GOOD EXAMPLE OF A "FIRST ORDER EFFECT." DARE WE TO THINK WHAT WOULD HAPPEN TO THE TAX SHELTER INDUSTRY IF WE EXTENDED "TAX FREE" STATUS TO INVESTMENT IN INDUSTRIAL AMERICA, AND THE VENTURE CAPITAL POOL.

Mr. **Brown** [presiding]. Thank you, Mr. Ritter. That is a very thoughtful and helpful statement.

I respect the fact that the course which you're proposing and the course which the Republican task force is proposing are essentially programs that do provide incentive and motivation; they are not institution-building recommendations; and this is a reasonable way to proceed.

But there always comes a time when you do have to make decisions about whether or not you may need to proceed to do something to improve the institutional structure. For example, the administration itself is moving in that direction with the Department of Trade.

And I'm wondering if there's any way that we could set a standard for when we want to improve our institutional capability, to focus resources, to make decisions, to examine policy implications, in order to achieve our national goals more effectively.

I'm asking you if you would comment on this process, because I think we went through this same kind of a thing.

I can imagine 30 years ago, when Vannevar Bush comes into the Congress and says, "We ought to set up a National Science Foundation," and Congressman X sat there and said, "We don't need a National Science Foundation; we've never had a National Science Foundation. We've always supported basic research through the resources of the States and the universities with a little help from private industry. Why do we need to do anything differently?"

What kind of criteria do we set? What are the points at which we can say, "Well, this problem is so serious that now we've got to take another look at it and decide on another course of action?" Can you shed any light on that?

Mr. **Ritter**. Well, first of all, let me say that I appreciate your comments, and, having worked with you for many years, I consider you one of the most thoughtful people in the Congress on these issues.

It seems to me that there is a role, an extensive role, for the Federal Government in doing the kinds of long-range research projects which—no one can argue with the—the intent or that peer review seems to establish that this is—this is the way to go.

The problem we get into as we begin to focus more on advance technology—and again our experience within the Federal Government is not necessarily that positive, as we have set up programs like synfuels, which the gentleman is quite familiar with.

Mr. **Brown**. It has been lousy in many situations.

Mr. **Ritter**. You know, it's much harder to find out where things are going. You know, us—people like you and me and the gentleman who just left, Mr. Jones—I mean our knowledge is extremely limited, and one of the bills—I think it's the Pashayan bill—talks about a study that would be set up like the Young Commission, like the Baruch Commission, but that it would take up to 3 years to come back with its findings.

Well, everything I hear from the people in the cutting edge of high technology and the applications of high technologies, they need answers in 3 weeks; they need to break ground; they need to expand; they need roads, sewage, communication lines, and clean rooms in 6 months; that has to be completed in order to take advantage of what's happening within the competitive markets.

The answer to your question is, if we can provide a greater mobility and flexibility to attack those markets, and sometimes to attack them in strength, such as the joint R&D ventures, such as in the case of antitrust and some of our basic industries, rationalizing the, quote, unquote, some of the older manufacturing industries so that they can modernize more effectively.

But I'm wondering how good we are here in Washington in addressing the location of the technological opportunities of the future.

I think we have to address concrete political arenas like the trade arena. We cannot pursue policies where we are Lilliputians and someone out there is a giant, although the Lilliputians at some point pinned Gulliver, but where these new technologies are is not easy to—to be better here than the market is out there.

Mr. BROWN. Well, we won't resolve that question today, but I noted that you, I think, commented favorably on the possible need to do something in the area of manufacturing technology, which is something that there's fairly good consensus on.

We—as a generic matter, we do need to upgrade the quality.

Mr. RITTER. I sincerely do, because we have let go, but the subsequent comments were, one of the reasons that that field languished was that it wasn't encompassed by the Federal R&D economy.

Mr. BROWN. Yes.

Mr. RITTER. And while the Federal R&D economy paid reasonably generous indirect costs to our research institutions, and while it covered substantial portions of faculty and research institute personnel salaries, if you went out and tried to do something with the local industry, you know, you got yourself $3,000, whereas a Federal grant could give you $30,000. We really skewed from here the innovation in manufacturing—the innovation away from manufacturing sciences, and technology.

So maybe you're right; it's time to skew back in the other direction.

Mr. BROWN. Well, we appreciate your contribution very much, and recognizing that you do have another committee responsibility——

Mr. RITTER. I thank you for your leadership in this and sincerely appreciate it.

Mr. BROWN. Thank you.

Our next witness is Mr. Robert P. Clagett, general manager, research and development, for AT&T Technologies, Inc.

That AT&T is a familiar name, but I'm not sure I recognize it's current manifestation there. You'll explain that to us, I'm sure.

STATEMENT OF ROBERT P. CLAGETT, GENERAL MANAGER, RESEARCH AND DEVELOPMENT, AT&T TECHNOLOGIES, INC., PRINCETON, NJ

Mr. CLAGETT. Well, the AT&T Technologies is what's left of AT&T—one half; the other half is AT&T Communications.

Mr. BROWN. We're very pleased to have your comments and your presence here this morning, Mr. Clagett.

Your full statement will appear in the record, if you should wish to abbreviate it or summarize it in any way, and you may proceed.

Mr. CLAGETT. All right. Thank you. I'd like to go over it in some part, in any case, because I'd like to make those points that might help further.

I'm general manager of research and development at AT&T Technologies. I'm here, however, because of my membership and activities in the Industrial Research Institute. The IRI is composed of heads of research in industry whose companies collectively represent over 85 percent of all industrial research and development being carried out in the United States.

I head AT&T's Engineering Research Center in Princeton, NJ. The center was established 26 years ago with the sole purpose of conducting research and development aimed at improving manufacturing research.

At that time, there were no models for such an R&D effort—that is, in manufacturing research exclusively. Today there are many. The center has been copied by Siemens in West Germany—I've had visits from the director there—from Nippon Electric in Japan, also visits—proud to be an exact copy of the engineering research center—and there are now many in the United States devoted exclusively to manufacturing research.

Our research ranges from advanced automation, robotics, laser applications in manufacturing, optical fiber processes, semiconductor processes, and, more recently, polymer processes, and, of course, electronic testing, statistical analysis, and computer-aided manufacture.

Since 1958, the research center has carried out an extensive program of manufacturing research and development, and it's resulted in significant developments in manufacturing process technology and, of course, has enhanced AT&T's ability to produce high quality and cost-effective products.

Research and development on manufacturing essentially entails engineering research conducted in close partnership with scientific research.

I am pleased, therefore, to see sponsorship of bills to advance engineering research because our experience at AT&T's engineering research center as well as the IRI members has shown research and development of manufacturing processes are very cost effective in giving industry competitive processes—that is, to devote specific effort in manufacturing research.

I feel the United States has not emphasized engineering research, as opposed to scientific research, enough, and I'd like to compliment the sponsors and the committee on focusing attention that will encourage and support engineering research, especially in universities, where we really receive a double benefit. First, of course, is the value of the research itself, but at least as important—perhaps more so—to the Nation is the value of educating engineering students in leading edge research.

At our research center, we have found whenever we tackle a problem, an interdisciplinary team is best. We don't assume that the problem will be one of a mechanical engineering type, or an electrical engineering, chemical, physics, or math; we assemble a team with a wide range of engineering and scientific backgrounds, because today's manufacturing problems involve all of them.

For example, it's no accident that AT&T Engineering Research Center developed the first industrial use of a laser. The apparatus is now in the Smithsonian.

In the early sixties, we assembled a team, shortly after the laser was invented, of electrical engineers, mechanical engineers, physicists, and material scientists to investigate laser applications to manufacturing. We still have such teams and a wide variety of research lasers now, and today we have over 500 lasers in our factories' working processes.

We also work in close collaboration with AT&T Bell Laboratories' engineers and scientists. Often Bell labs will create a product concept, quite often with new materials, and the engineering research center will work with them to develop an efficient manufacturing process.

As an example, when the labs developed a product concept that used tantalum thin film, it had to be deposited in a vacuum, and at that time we were using bell jars to create those vacuums.

Obviously, there was a need to do something other than to have acres of bell jars in a factory, and so the engineering research center used an interdisciplinary team to develop a process that would move parts in and out of that vacuum at high rates to create a high quality, low cost film. We did so. It resulted in an in-line vacuum machine that was ready for production when the product design was finalized.

Well, I cite these examples to emphasize my conviction that, based on our experience, interdisciplinary teams are very important, indeed necessary, for most creative solutions to today's complex manufacturing problems, and I therefore would like to encourage you to find ways, as you move to support engineering research, to also emphasize the close collaboration between engineering and science.

One way you might consider doing this would be to link the new engineering research emphasis to existing science research programs and agencies, for example, expanding the role and charter of the National Science Foundation, as has already been proposed, to include not only funding and emphasis on engineering research, but on programs and concepts to enhance engineering and science collaboration would be a great benefit to the Nation, I believe.

This, of course, should not be done at the expense of the current scientific research, which is quite important. Such a change may be more efficient, however, and help in your perceptive emphasis on coordination and communication among Government agencies, universities, and industry.

Better communication and information exchange among engineering research, scientific research, and especially interdisciplinary teams throughout the country will greatly enhance the U.S competitive position.

AT&T is a member of the Industrial Research Institute because we want to be a part of an effort to promote improved economical and effective techniques of organization and operation of industrial research, and that is the goal and aim of IRI, at which they work rather hard.

As I talk to individual members of the IRI, I find they feel as I do that the need in this country is to provide incentives and focus for private industry to carry out industrial research as well as a need to emphasize and aid engineering research in our universities; I emphasize engineering research.

For example, in the emerging fields of robotics research, there are many programs in industry. I have one of substantial size at ERC. There are also many university programs under way or being developed.

The need is not so much to create additional research centers as it is to support and fund university equipment so that it is current, leading edge equipment, and to develop communication among the many researchers.

There are existing programs at both the National Science Foundation and the National Bureau of Standards that are a good start. Your emphasis and focus is needed to fund and enhance those programs to maximize the Nation's resources, I feel.

And, finally, I'd like to come back to my main point that as the committee deliberates on ways to enhance the U.S. position in engineering, the value of interdisciplinary research, engineering, and science can be a powerful adjunct to any aid and programs they create to strengthen the United States.

Thank you.

[The prepared statement of Mr. Clagett follows:]

UNITED STATES HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON SCIENCE, RESEARCH & TECHNOLOGY

Statement of
ROBERT P. CLAGETT

June 12, 1984

My name is Robert P. Clagett. I'm General Manager, Research and Development, AT&T Technologies. I have been asked here because of my membership and activities in the Industrial Research Institute. The I. R. I. is composed of heads of research in industry whose companies collectively represent over 85 percent of all industrial research and development being carried on in the United States.

I head AT&T's Engineering Research Center in Princeton, New Jersey. The Center was established 26 years ago with the sole purpose of conducting research and development aimed at improving manufacturing processes. At the time, there were no models of such R & D -- today there are many. The Engineering Research Center has been copied by Siemens in West Germany, Nippon Electric in Japan, plus many in the United States. Our research ranges from advanced automation and robotics to laser applications in manufacturing to optical fiber processes, semiconductor processes, polymer processes to electronic testing, statistical analysis and computer-aided manufacture.

Since 1958, the Engineering Research Center has carried out an extensive program of manufacturing research and development, which has resulted in significant developments in manufacturing process technology and has enhanced AT&T's ability to produce high quality cost effective products. Research and development on manufacturing essentially entails engineering research conducted in close partnership with scientific research.

I am pleased, therefore, to see sponsorship of bills to advance engineering research because our experience, as well as that of I. R. I. members, has shown that research and development of manufacturing processes are so cost effective in giving industry competitive processes. I feel the U. S. has not emphasized engineering research enough. I would like to compliment the sponsors and the Committee on focusing attention that will encourage and support engineering research, especially in universities where we have a double benefit. The first benefit has been the value of the research itself to the nation's industries; and, equally important, has been the value of educating engineering students in leading edge research.

At the AT&T Engineering Research Center, we have found that whenever we tackle a problem, an interdisciplinary team is best. We do not assume it is a mechanical engineering problem, an electrical engineering problem, a chemical problem, a physics problem or a mathematical problem. We assemble a team with a wide range of engineering and scientific backgrounds, because today's manufacturing problems involve them all.

For example, it is no accident that the AT&T Engineering Research Center developed the first industrial use of a laser. The apparatus is now in the Smithsonian. In the early 60's, we assembled a team of electrical engineers, mechanical engineers, physicists and material scientists to investigate laser applications to manufacturing. Similar teams are still finding new applications, and today we have over 500 lasers at work in our factories.

We work in close collaboration with AT&T Bell Laboratories' engineers and scientists. Often Bell Labs will create a new product concept using new materials, and the Engineering Research Center will work with them to develop an efficient manufacturing process. For example, Bell Labs' scientists developed a product concept that required thin tantalum films to be deposited in a vacuum. The Engineering Research Center, using an interdisciplinary team, worked to develop a process so that parts could be moved in and out of a vacuum at high rates to create high quality, low cost films. The result was an in-line automated vacuum deposition machine which was ready for production when the product design was finalized.

I cite these examples to emphasize my conviction, based on our experience that interdisciplinary teams are important, indeed necessary, for the most creative solutions to today's complex manufacturing problems. I would therefore like to encourage you to find ways, as you move to support engineering research, to also emphasize close collaboration between engineering and science.

One way you might consider doing this would be to link the new engineering research emphasis to existing science research programs and agencies. Expanding the role and charter of the National Science Foundation, as has already been proposed, to include not only funding and emphasis on engineering research but on programs and concepts to enhance engineering and science collaboration would be a great benefit to the nation. This, of course, should not be at the expense of the current scientific research. Such a change may be more efficient and may help in your perceptive emphasis on coordination and communication among government agencies, universities and industry. Better communication and information exchange among engineering research, scientific research, and especially interdisciplinary research teams throughout the country will greatly enhance the U. S. competitive position.

AT&T is a member of the Industrial Research Institute because we want to be a part of an effort to promote improved economical and effective techniques of organization and operation of industrial research. As I talk to individual members, I find they feel as I do that the need in this country is to provide incentives and focus for private industry to carry out industrial research, as well as a need to emphasize and aid engineering research in our universities. For example, in the emerging field of robotics research there are many programs in industry. There are also many university programs underway or being developed. The need is not so much to create additional research centers as it is to support and fund university equipment and to develop communication among the

the researchers. There are existing programs at both the National Science Foundation and the National Bureau of Standards that are a good start. Your emphasis and focus is needed to fund and enhance these programs to maximize the Nation's resources.

Finally, I would like to come back to my main point that as the Committee deliberates on ways to enhance the U. S. position in engineering, the value of interdisciplinary research -- engineering and science -- can be a powerful adjunct to any aid and programs they create to strengthen the United States.

I would like to thank you for the opportunity to comment on these very important deliberations.

6/12/84

ROBERT P. CLAGETT (BOB)
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B.S. - University of Maryland
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Mr. Clagett began his Western Electric career in 1956 at the Baltimore (Md.) Works, holding engineering assignments there and at the Engineering Research Center in Princeton, New Jersey. He advanced in supervisory ranks with assignments in Manufacturing, Bell Sales, Corporate Engineering, and Product Planning. Currently he heads the AT&T Engineering Research Center in Princeton, New Jersey.

Mr. Clagett served as chairman for the National Communications Forum and the National Electronics Conference for the year 1978. Currently he is a member of the Educational Council of the Massachusetts Institute of Technology, and is a Visiting Professor at Rutgers University.

Mr. **Brown**. Thank you very much, Mr. Clagett, for your very helpful presentation.

Mr. Clagett, can you give me any clues as to the size level of an organization at which it becomes justified to do the sort of thing that AT&T has done—that is, to create an engineering research capability? You were unique when you started that.

Mr. **Clagett**. Yes, we were.

Mr. **Brown**. I'm interested in when it becomes feasible and desirable, and what are the circumstances that create the motivation to do this, which, in retrospect, seems to have been such a useful step for you to take.

Mr. **Clagett**. Well, I believe we started because at that time we were fairly unique in that we had our design of our product by the Bell Laboratories.

Remember, we were then vertically integrated. We were at the time much involved in the new semiconductors. The first transistor had been made at our plant in Allentown, PA, just a few years before we started, and the problem was to develop long-range manufacturing research, frankly, away from the factory.

The factory environment to do long-range research isn't so good. You get problems on the factory floor, and the foreman calls your engineers in to solve those problems, and so that's tough.

We started by moving some of our better engineers from around our factories to a separate location with about 30/35 people, and we did good research at even that level.

So it doesn't take a huge effort. What it takes is some small portion of dedicated people focused on those kinds of problems, and even at that small level, the research teams were interdisciplinary.

Now I must say, I was there at that time in 1958. Since I've been back the last 4 years, the character of that research center—we have about 500 people, about 200 professionals—and the research has changed, because today we have many more advanced degree people and a wider variety of disciplines. What I see today is a much better understanding of the science of the work that we're doing, which is quite powerful. That allows you to reapply it.

So I would think that, to answer your question, the firm does not have to be too large to devote specific effort to manufacturing research. Both the Siemens effort and the Nippon Electric effort is about half that—about 250 people.

Mr. **Brown**. In terms of the size of the engineering research effort to the size of the institution, let's look at budgets. Are we talking about a fraction of a percent that goes into the research effort—a fraction of 1 percent or something like that, or is it 2 or 3 percent?

Mr. **Clagett**. Well, I would say for our company it probably is somewhere between 1 and 2. Remember that my budget is quite small, but then I work with all the manufacturing engineers at our factories.

Mr. **Brown**. Yes.

Mr. **Clagett**. Any of the research we do doesn't mean anything unless it's implemented and put in the factory. So I really must say that the engineers and scientists at our factories, and that includes branch groups of Bell Laboratories at those factories, really multiply what we do by applying it. It's still relatively small.

Mr. **Brown**. Yes. I'm trying to see how this fits into some of the other things.

For example, in some of our defense contracts and other contracts, we allow a small percentage for independent research as a part of the contract. It's almost comparable to what you're talking about in terms of your budget here.

Mr. **Clagett**. Yes.

Mr. **Brown**. It's on the order of 1 percent or something like that.

Mr. **Clagett**. Yes.

Mr. **Brown**. So it is not out of line that an enterprising organization would focus this kind of resources on their problems.

Were you motivated to move into it at the time you did because you were also undergoing a fairly substantial change in technology?

Mr. **Clagett**. No question.

Mr. **Brown**. Semiconductors versus vacuum tubes or whatever it was, so that you felt the need to have this additional kind of thing? You weren't facing the prospects of bankruptcy or anything like that, were you?

Mr. **Clagett**. Not at that time; no.

Mr. **Brown**. No.

Now the question that I have is why an organization like yours proceeded along this path, which has been so valuable, and other organizations and industries did not. And we'll take a look at one that gets a lot of brickbats at this time, the steel industry.

The steel industry has never seemed to feel the need to devote resources to research in manufacturing technologies, at least to my knowledge. Now do you have any knowledge that contradicts this?

Mr. **Clagett**. I don't have any knowledge that contradicts it; no. I've often wondered, too. They have done a lot of work on materials, but on the processes, I have to agree with you, my impression is, not too much.

Mr. **Brown**. Yes. Well, they may have felt that they had reached perfection in manufacturing processes for steel and that there was no need for additional——

Mr. **Clagett**. Well, I'm not sure that it was the research. I know some of the research facilities—for example, one fairly near us in Bethlehem that Bethelehem Steel has—but I'm not sure about implementing those in industries like the steel industry in terms of getting rid of the old processes, the huge capital investments in the old processes, versus recapitalizing for the new ones.

I do know, of course, as you do, that there is and was even a greater difference between the depreciation rates in the competitor nations—Japan and West Germany—versus ours that surely would have encouraged over time modernization of those plants, so I'm not sure.

It would be interesting to see if they didn't develop the processes but couldn't afford to put them in place.

Mr. **Brown**. Well, there's no question but what the tax structure has a much greater effect on decisionmaking than almost anything else, but it seems to me that any large-scale industry or enterprise ought to protect its future income and status with a small amount of research that's aimed at exploring the future, basically, and too many of our industries aren't doing that.

I heard on the news in the last day or two, that the Bethlehem plant at Sparrows Point is just beginning to modernize with a continuous caster. Continuous casters are not a new technology.

Mr. CLAGETT. That's right.

Mr. BROWN. They are an old technology, and they may be waking up just one generation too late to the need to modernize. But that's another point.

What I'm basically trying to explore with you are the factors here which are conducive to our maintaining our technological superiority and leadership in this country, and I sometimes am forced to the conclusion that it's not what government does or what most industries do, it's due to some upsurge of wisdom and leadership at a particular time and place, which is very hard to create.

Mr. CLAGETT. Yes, it's hard to create, but—I fully agree with what I think you are saying. I get a feeling that, indeed, industry, government, and university now see the need in the United States to emphasize engineering research and manufacturing research, and they are all doing it.

I do believe there is still a problem, of course, as I mentioned, of having the cashflow to put in new facilities, but one of the major problems we now face is creating enough engineers, especially advanced degrees who have the research knowledge. We are increasing at the bachelor level in our enrollment, but not at the master's, and in fact are dropping at the Ph.D. level, and we need to emphasize that.

That's why I feel that the one thing that could be done would be some help to the universities, not only research programs, but especially in equipment for that research. That would not only give better research out of those universities but then would allow those students, of course, to be familiar with the current state of the art.

Mr. BROWN. Now, does the Industrial Research Institute ever undertake to make policy studies and recommendations based upon the experience of its members that really represent the core of our research capabilities?

Mr. CLAGETT. Yes. Yes; it has in the past.

Mr. BROWN. Because that could have a powerful influence on the decisionmakers, both in the corporations as well as in the political setting, and maybe the university setting, too.

I observe that the National Academy of Engineering is doing a study on the needs for engineering research. Are you participating in that?

Mr. CLAGETT. Yes. I'm on a subcommittee of the manufacturing board of the research council sponsored by it.

Mr. BROWN. It seems to me that that can do a useful job in terms of sensitizing our corporate and political leaders to the needs for possible changes in policy here also.

Mr. CLAGETT. Yes, and the academy is going to have a forum in the fall focused just on that.

Mr. BROWN. Well, basically this hearing, you know, is an exploration of what it is that we could be doing, should be doing, can do, that might help us achieve these national goals.

We're sometimes accused of trying to subvert the government or society with these proposals, but that's not really the purpose here.

Most of us in Congress and on this committee are aware that there are problems which have been festering here for a number of years and which we don't seem to be moving on.

Now I'm not totally pessimistic. A lot of good things have happened. This release of capital funds as a result of the changes in the capital gains laws has been an impressive achievement for the beginning of a lot of new research and development type activities, as Congressman Ritter pointed out, but we still are a long way from achieving everything that we need.

You haven't come down on any particular recommendations as far as the legislation before us is concerned, have you?

Mr. **Clagett**. Well, I think in general that it would be better to focus whatever funding could be made available to enlarge the engineering research charter of the National Science Foundation.

Mr. **Brown**. Well, we are moving in that direction, you know.

Mr. **Clagett**. That would be a plus.

Mr. **Brown**. We're expanding the budget there in the foundation. We're emphasizing this need that you have stressed. We've dignified the activity a little more by some cosmetic changes, and we may be able to see some results there which will be a tribute to the awareness of the science foundation of the significance of this, too.

Mr. **Clagett**. Yes. And then, as I said, I would like to see emphasis—and it might be part of any such change—substantial emphasis on interdisciplinary research and communication. I believe that's quite important in our future.

Mr. **Brown**. Do you have any questions of this witness?

Mr. **Walgren**. No.

Mr. **Brown**. OK. All right. Thank you very much, Mr. Clagett.

Mr. **Clagett**. Thank you.

Mr. **Brown**. Our next witness will be Dr. Russell Drew, vice president for professional affairs of the IEEE, which I'm told is the largest organization of professionals in the world, or some fantastic story like that.

STATEMENT OF DR. RUSSELL C. DREW, VICE PRESIDENT FOR PROFESSIONAL AFFAIRS, INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS

Dr. **Drew**. Yes, Mr. Chairman.

We're now celebrating our 100th year of electrical progress, and we're very proud of the history and tradition and, in fact, the record of involvement in matters in which we share a great deal of common concern with this committee.

I certainly wanted to compliment the committee on its hearings and on the challenging agenda that it's put before public policy makers in this area of technology policy.

As I say, it's an area that we in the IEEE have attempted to deal with and have addressed in a number of ways, and I'd like to share some of the views of the IEEE and perhaps some of my personal views to supplement those.

I come from the small business community now, and I'm afraid my view of the health of the manufacturing technology industry in the United States perhaps is slightly different than AT&T's or IBM's or the GE's and Westinghouses.

Mr. **Brown**. It's no less important than those, is it?

Dr. **Drew**. No, sir. I would like to suggest in my remarks today that perhaps small business may be just the catalyst that makes the larger part of our system respond and maintains their muscle tone, if you will, and gives them the challenges that cause the entire private sector in the United States to work the way it does. That may be a slight overstatement, but in any event I think I believe it.

I'd also like to start out on the premise that we all share a conviction about a commonly heard adage, and that is, "if it ain't broke, don't fix it." There is much in the technology policy of the United States which is right. There's much about the U.S. industrial system that is working right.

Just today, if you look at the analysis of what's happening in Europe, you find in the morning newspaper a report that the Europeans, despite large centralized planning and investments, are still looking to the United States as the technological leader. The objective that they have to try to somehow or other keep pace with and the targets to which they are trying to move really lie in the achievements that we have made here in the United States.

So I think we start out with the premise that basically we have a very solid system, and the things that we have been doing have been achieving generally positive results, but yet in the preambles to the legislation that you've asked us to comment on this morning, there are a number of problems which, in fact, show that not all of what exists is right.

There are some problem areas, and those problem areas, I would agree, really can respond positively to a sensitive, perceptive application of Federal policy and Federal attention.

The marketplace, which you have heard a great deal about, I'm sure, in all of these hearings, and we've heard about a great deal in the public policy domain for the last 3 years, is indeed an effective regulator. It's an effective stimulant, and it's an effective mechanism for weeding out some of the less productive parts of society.

But I would suggest to you that more and more analysis seems to illustrate that in that marketplace there are disincentives that exist that, when you begin to look at them and you relate them to what's happened to our competitiveness in a number of areas, show that the private marketplace has some significant defects.

Corporate management isn't omniscient, and they're not endowed with the abilities that were pointed out this morning are also not available to government bureaucrats. In fact, people respond to the incentive systems that exist, and the incentive systems that exist today in corporate America tend to favor the short-term benefit—the positive, bottom line effect of short-term investments rather than the longer term investments that I believe are also necessary in terms of R&D and in development of new product areas.

It's in that vein that I believe a very useful example of Government operating in a quite positive way is the NASA history that was mentioned here earlier this morning. That aeronautical research and development has had a very positive effect; it's been stimulative; it's opened the doors to new products in the aviation industry that would not have been possible if we had just left the marketplace to have its own way.

So in considering the two bills—the National Technology Foundation and the other bill which is very close to it in some ways, the Advanced Technology Foundation Act—we like to come down on the positive side and suggest that we think there is a definite benefit in pulling together a number of these functions and addressing what is a very large gray area between basic research support on the one side, in which, in general, everybody tends to agree government has a very principal role, and commercialization—the actual development of products which are going to be sold on the marketplace there, on the other hand, the private sector people who are going to have to worry about marketing, selling, making a profit, really have the essential role.

And then there are some connecting linkages between those extremes which I've called this gray area, and it seems to me that gray area is the sort of thing—it's the proper focus for the institution, the National Technology Foundation, or perhaps an Advanced Technology Foundation.

So for the most part, we would tend to agree with the functions and with the assigned responsibilities. I'd like to highlight a few exceptions, however.

One, is the question of the engineering directorate in the National Science Foundation and a recognition of what is happening at the National Science Foundation today, which basically is a reawakening, if you will, to engineering research needs. We've seen both in the more explicit recognition of engineering in their legislative mandate and in requests for additional funding.

We think that's moving in the right direction and that such research belongs in an institution where comparable research is being funded, where the institutional orientation is toward support of university research. So that looks like it probably ought to stay where it is.

There are a number of other pieces which address this gray area, however, which seem to us to belong in an institution where they can be given the principal attention. They're not given that today at NSF, and with all due respect for the efforts of the Department of Commerce and the Office of Productivity, Technology, and Innovation, that hasn't worked either. We haven't had enough dedicated attention to this area in order to bring about the kind of positive effect that we'd like to see.

So, in general, we support the kind of amalgamation of these functions into a separate institution where they would be the principal objective.

It need not become a very large granting institution, and as a matter of fact there are some specific provisions of the Advanced Technology Foundation Act that would cause us some considerable uneasiness. Principally, that has to do with large-scale grants for industrial development, which smacks of the industrial policy of shoring up weakening industries, et cetera. That's a political game, and it will be subject to all sorts of political pressures, and I don't think the net effect will be positive. So we would like to see some of the functional roles played out, but not with this very large open-ended grant authority.

One of the functional roles for a new institution, by the way, is the Federal Industrial Extension Service. We would support that, and we see in fact that this provides a nice basis for bringing those two bills together perhaps in some amalgam where the Industrial Extension Service would not be lost, and would in fact become part of, say, a National Technology Foundation.

The recipients, or the benefits, of such an extension service are going to be largely in small business, not big business, and so looking at it from my end and being in the midst of a product development cycle right now, I can see the benefit of being able to reach out and utilize such a service if, indeed, it existed today. Unfortunately, it doesn't.

I'm in northern Virginia, and we are going to receive a high technology center sometime downstream. I could use some of those services today. And so we are finding other ways of trying to accomplish that purpose.

As a consequence, however, I can see the benefit of this industrial extension service and would like to see it become part of any amalgam that you may be considering. We in the IEEE would be very happy to provide our additional thoughts and perhaps some assistance if you are thinking about redrafting the legislation with that in mind.

All right. Let me go on to the other two bills which basically call for studies.

I would like to point out that we are opposed to those, not that we don't support the statement of the problem; it's just that solving the problems in the ways that are described strike us as being entirely too oversimplified, and it's largely a mission impossible.

So we think that chartering such studies would be largely a waste of money and time and that the large, global study which deals with all of the problems and tries to wrap them up—which, in fairness, has been tried before, I think, in various national commissions, going back at least probably 20 years—just really doesn't get you very far. More than likely, putting the institutional structure that we're talking about in place, giving it an assigned responsibility, and an adequate budget, will be a much better course of action.

I think the other one point that I wanted to raise is a point in reference to a small provision in the Advanced Technology Foundation Act which talks about making loans to assist in the commercialization—in other words, the R&D leading to commercialization. That provision could be labeled something like the NRDC, which exists in the United Kingdom, and in the United States we have resisted that for some time.

I wanted to point out to this committee—and I would assume you are probably aware of this, but let me point out that the United States has supported such an institution in the Bi-National Industrial R&D Foundation, which operates on the basis of an endowment that was funded by the United States and by the Government of Israel. The objective of that foundation is to do precisely this—is to make R&D investments that will lead to commercializable products on a basis for which—in which there is repayment of that R&D investment to replenish the fund.

That has been working quite well. The success rate has been very high, and it does appear as if there are things which are coming on line which may not have indeed been developed without that type of support. So, in general, I would be in favor of doing something like this on a relatively small scale.

The Bird Foundation operates on—started operating on a small scale of about $3 million a year from their endowment. It may be true that the larger you get, the more unwieldy and impossible it is to get good products or good projects, but I think it would be worth doing this or beginning to open the door to this possibility. I think it would provide some stimulus, primarily for smaller businesses, and it is the small businessman and what he can provide as a challenge for the larger business structure of this economy which I think is one of the keys to our success.

Well, I have tried to hit some of the highlights of my testimony, Mr. Chairman. I'd be happy to answer any questions you may have.

[The prepared statement of Dr. Drew follows:]

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TESTIMONY

OF

DR. RUSSELL C. DREW

OF THE

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

BEFORE THE

SCIENCE, RESEARCH AND TECHNOLOGY SUBCOMMITTEE

OF THE

HOUSE SCIENCE AND TECHNOLOGY COMMITTEE

JUNE 12, 1984

REGARDING

H.R. 481, THE NATIONAL TECHNOLOGY FOUNDATION ACT

H.R. 4361, THE ADVANCED TECHNOLOGY FOUNDATION ACT

H.R.1243, THE ECONOMICALLY STRATEGIC INDUSTRIAL RESEARCH AND DEVELOPMENT ACT

H.R. 2525, TO ESTABLISH A NATIONAL COMMISSION ON TECHNOLOGICAL INNOVATION AND INDUSTRIAL MODERNIZATION

Mr. Chairman and Members of the Subcommittee:

It is a great pleasure to respond to your invitation to testify today on technological innovation in the United States. This is a matter that has been of major concern to me personally and also to the Institute of Electrical and Electronics Engineers (IEEE), in which I serve as the Vice President, Professional Activities.

The IEEE is the world's largest technical professional society, with about 250,000 members, of which over 200,000 live and work in the United States. Our members work in industry, government, and academia, and over the past decade have become much more involved with the public policy process in government. The range of issues that are of concern to us is rather large, in keeping with the diversity of our membership and the expertise they possess.

Many of our interests fall within the rubric "U.S. technology policy", and it has been our practice to sponsor a major conference on this topic here in Washington, currently on a biennial basis. In this way we have sought to focus attention on specific aspects of technology policy and to bring out various perspectives regarding both major issues in the area as well as suggested corrective measures.

It is therefore particularly encouraging for us to observe the active concern for such issues that has been reflected in the topical hearings conducted by this subcommittee. We applaud your continuing efforts to develop more effective technology policy for the U.S. and hope we will be able to contribute to your deliberations from time to time. In accordance with your request, my remarks will be addressed to four bills, H.R. 481, H.R. 4361, H.R. 1243 and H.R. 2525.

H.R. 481, THE NATIONAL TECHNOLOGY FOUNDATION ACT OF 1983

It was in connection with the 1979 IEEE U.S. Technology Policy Conference that one of our leaders, Dr. Bruno O. Weinschel, first discussed the concept of a National Engineering Foundation as a vehicle for carrying out a number of functions that appeared important to address our growing concern about the international competitiveness of U. S. industry. Dr. Weinschel's perspective was further elaborated in his testimony before the Senate Governmental Affairs Committee on July 25, 1979, addressing the concept of a Department of Trade. Although some of these functions were either in the general responsibilities of existing entities or could be incorporated in them, it was felt that a new structure was needed to give the necessary emphasis to technological development issues. Over several Congresses, this structure has evolved to the current form represented by H.R. 481, which you are considering in these hearings.

In general, we support the establishment of such an institutional structure as an important step in improving the way in which government deals with its policies regarding technological innovation. We have reservations about specific provisions in the proposed legislation, but the concept seems sound and the result would be an improvement in the development and implementation of technology policy.

On the positive side, the NTF would bring together for the first time under a separate management structure many of the various entities that have missions in the large gray area between basic research, where the government role is well understood and accepted, and commercial application, where nearly everyone agrees the government involvement should be minimal. It is in this gray area where I believe the most important and creative roles for government to stimulate innovation lie. This is an area that primarily involves engineering rather than basic science, but builds upon the insights and discoveries of the research community---both in science and in the engineering disciplines. The NTF would permit a strong management to develop, with a substantial analytical capability, in order to refine and make more effective the Federal efforts in this area.

The challenges facing the management of the NTF are substantial. Among others, there is the effective implementation of the Stevenson-Wydler Act of 1980, including an expansion in the number of generic technology centers over those sponsored by the NSF. Another important area covered in the bill is support for high technology small business. Such small businesses are a key part of our industrial infrastructure and supply many of the new products that keep our marketplace so dynamic. Government has already taken action to give greater R & D opportunities to small business through the Small Business Innovation Research Program mandated by P.L. 97-219. In this program the major R & D performing agencies have been given the responsibility of contracting for R & D in the small business community where agency practices have generally resulted in by-passing small businesses. I believe that this program, in addition to the benefits it will bring to the agencies involved, will also have a beneficial effect in stimulating industrial innovation across a broad front.

It is this type of creative use of a Federal stimulus, either through financial or other support, especially where market defects exist, that can be carried out by the NTF. I don't believe that we've been clever enough or perceptive enough to have invented all the beneficial ways that government can act to assist the process of technological innovation. What seems clear to me is that the existing structure where such actions would be carried out is either fragmented or buried inside larger entities in which these issues are not major concerns, and because of this we are not doing as well as we might in applying our national technological capabilities.

Earlier this year, I appeared before this subcommittee to testify on the budget of the National Science Foundation, and on the proposal to include engineering more explicitly in its legislative mandate. At that time, I expressed our support for changes in the NSF charter that would place additional emphasis on its engineering mission. This support was given with full recognition that H.R. 481 would assign this role to the proposed National

Technology Foundation. Today, I wish to reaffirm our support for increased emphasis on engineering in the NSF. As a consequence, we do not endorse the transfer of the Engineering Directorate to the NTF as proposed in H.R. 481. We base this position on two major factors: one, the process that engages most of the budget of the Engineering Directorate is support of research in the engineering disciplines mainly at colleges and universities and this support is best managed in an agency where the health of basic research is a primary mission; and two, the recent recognition of engineering needs by the National Science Board and the Director of NSF which indicates greater sensitivity to, and willingness to support, priorities for increased funding of research in engineering.

The linkages between the research community and the industrial practitioner are also important to the innovative process, and both the NSF and the NTF could encourage such programs with financial and other support. Basically, my image of the proposed NTF is not as a parallel entity to the NSF, focusing on engineering instead of science, but rather as a complementary institution which deals primarily with the large "gray area" between the output of the research effort and its transfer and application to the industrial or governmental setting where it can be most useful.

H.R. 4361, THE ADVANCED TECHNOLOGY FOUNDATION ACT

The role I have outlined for the NTF is closely related to the provisions of H.R.4361. Earlier this year, I also testified before the Committee on Banking, Finance and Urban Affairs on this bill. The basic message that I attempted to convey was one of shared concern over the problem of technological innovation in the U.S., toward which the proposed Advanced Technology Foundation is pointed, but some reluctance to endorse all of the features of the Foundation's assigned programs.

One of the more creative features of this legislation is the proposal to establish a Federal Industrial Extension Service (FIES). If the FIES operated in the same way as the agriculture equivalent, it should be of great benefit to small business or the entrepreneur and would strengthen this important part of our industrial infrastructure. However, H.R. 4361 also includes a provision that would direct the FIES to "provide grants and loans to carry out industrial extension plans and programs". This would have the affect of substituting government intrusion into the marketplace in place of valid and quite satisfactory criteria for the investment of private capital. That is, as a result of interest group pressure, it may extend the life of non-essential industries that are truly declining rather than better investing the resources toward nurturing newer, and therefore possibly less well politically represented, technological and industrial sectors. We oppose such provisions as unnecessary and quite likely to result in an unfortunate skewing of the private capital market.

Where the market is already skewed or biased, however, there may be an important role for the Federal government to help fill gaps or to provide missing incentives. This appears to be the case in industry today where the emphasis upon short term financial performance---the "bottom line"---leaves longer term R & D investments under-funded. The problems caused by attention to short term profitability at the expense of longer term investment have also been exacerbated by a variety of corporate management problems, such as lack of technological training and awareness at top management levels, lack of appreciation for advanced quality control techniques, lack of attention to manufacturing technology improvements, and poor labor practices. These are problems which the Federal government cannot easily address. Providing information and analysis to guide corporate decisions is probably the approach that would have to be taken.

A more active role may be desirable in the case of the under-investment in longer term R & D. Here there may be a role for loans or other types of repayment contracts for projects intended for eventual commercialization, but which are too long term for the private capital markets to support. This provision is part of H.R. 4361. It is very much like the National Research and Development Corporation (NRDC) in the United Kingdom, which has been in operation for a number of years. While there have been mixed reports about the utility of the NRDC and its ability to make wise choices for investment, a very similar organization which has been in operation between the U.S. and Israel has had a very high success rate. This organization, the Bi-national R & D (BIRD) Foundation, was established with an endowment of U.S. and Israeli funds with the objective of financing joint R & D projects that would lead to commercial products. A repayment provision for successful products is used to replenish and build the fund. From reports I have received, the BIRD Foundation has operated in a highly successful manner, and there is a reasonable prospect that such a fund operating solely in the U.S. could also be operated successfully.

In summary, these two bills address the same generic problems, and have a large number of attractive features. It would appear that an amalgam of the two bills, eliminating the features that I have described, would make a very attractive package. We in the IEEE would be pleased to provide whatever assistance we can to aid in carrying out this task.

H.R. 1243 AND H.R. 2525, THE ECONOMICALLY STRATEGIC INDUSTRIAL RESEARCH AND DEVELOPMENT ACT, AND A BILL TO ESTABLISH A NATIONAL COMMISSION ON TECHNOLOGICAL INNOVATION AND INDUSTRIAL MODERNIZATION.

Both of these bills in essence define studies that are to be conducted, one under the direction of the National Academies and the other by a special commission. In both of these bills, there are a number of serious national concerns enumerated and problems identified which are real and of current interest. Unfortunately, the assumption of both of these bills is that a study, either by experts or by politically attuned groups will be able to offer solutions to these problems.

For example, it is suggested that, in H.R. 2525, a national industrial strategy could be defined, including a comprehensive plan with legislative recommendations. In addition, there are to be recommendations on how to deal with such diverse and complex problems as economic, educational, and industrial priorities; education and training of students and workers for future job skills; retraining of workers; extending new technologies to all America's basic industries; promotion of exports; relocation of high growth industries into areas of unemployment; etc. Many of these issues are highly resistant to simple solutions, and each one of these topics would be a very challenging task to study, with the mandate that is included in the bill. It seems an impossible task to lump them all together much less to assign a very tight time limit for the preparation of recommendations.

A very similar circumstance applies to the study of "economically strategic technologies". The output of such a study, if it were to be carried out, would have the character of a national economic plan. Such planning seems inappropriate in a democracy, and particularly in such a large and complex economy as the U.S. where the marketplace plays such an important role. My expectation is that the result from such an effort would be partly trite and obvious, and partly unbelievable, and I would not want Federal policies set on such a basis.

In summary, we are opposed to the actions proposed in these two bills, while concurring in their statements of the problems to which they are addressed.

This ends my prepared statement, Mr. Chairman. I will be pleased to respond to any questions you may have.

DR. RUSSELL DREW

Dr. Drew received his Bachelor's degree in Engineering Physics from the University of Colorado in 1953 and his Ph.D. in Physics from Duke University in 1961. From 1976 to 1977, he served as the Assistant Director for National Security Affairs of the Office of Science and Technology Policy, Executive Office of the President. He was Director of the Science and Technology Policy Office at the National Science Foundation from 1973 to 1976 and was a Senior Staff Assistant in the Office of Science and Technology from 1965 to 1972. He is currently President of Science and Technology Consultants, a small business involved with development of scientific instruments and technical consulting services.

Dr. Drew is Vice President of Professional Activities of the United States Activities Board of the IEEE and has chaired the IEEE Technology Policy Conference held in Washington, DC. Dr. Drew specializes in Science and Technology Policy matters and application of technology to advanced instrumentation.

Mr. **Brown**. Thank you very much, Dr. Drew.

First let me say that from the standpoint of the committee, I think that we do look forward to continuing to work with you and the IEEE on refining any proposals that we have before us that seek to bring about a better situation in this area of technological innovation.

I would say that we have a continuing responsibility for at least observing and evaluating the effects of what we are currently doing as well as suggesting new ways to do these things better, and if we do our job properly, it will be beneficial.

Let me offer one comment with regard to your general statements about the inadvisability of attempting to do much in the way of targeting or planning for particular industrial segments.

I think that you were correct in your opening statement when you said that the Europeans look to us as leaders, in part, because we do have a greater amount of freedom. We don't seek to constrain activities through national planning, and probably the best example of the weaknesses of that are in the agricultural sector of the European Common Market, which is planned, supported, subsidized, and is probably the least efficient part of the European economy and is about to bankrupt the whole economy as a result of that.

Now there are reasons for that, and they are endemic in any Government operation. The agricultural sector is powerful politically and is able to get what it wants through the political apparatus rather than through the operations of market decisionmaking, you might say. That can happen in this country in sectors other than agriculture. It happens in agriculture, too, here. But it's a good example of why you have to be careful in seeking to have government intervention in something that can be better controlled by market processes.

Having said that, I think there is still a role for Government in some areas.

I would like to compliment you on the way you distinguished the role of the National Technology Foundation. I think you are precisely correct there, and I want to give some thought to your suggestion that we shouldn't remove the engineering activities from the National Science Foundation because it's more important to maintain the activities in an environment which supports university research.

You have thought about this pretty seriously, have you? You don't see any possibility that the engineering may tend to get somewhat slighted because of the greater influence of the scientific disciplines as compared with the engineering disciplines here? Not that engineering isn't scientific.

Dr. **Drew**. Well, Mr. Chairman, I believe that first of all, the National Science Foundation is sensitive to its constituencies. It tries to listen, and I think has, by and large, done a pretty good job of doing that. So the emphasis on engineering has been in response to a much more aware engineering community, I think. In the past this strong tendency to support the sciences and perhaps to allow engineering to take a very, very minor role reflected the fact that the science community had mobilized, if you will, that they were sensitive to what the NSF meant to their communities.

You had the astronomers, for example, doing periodic and quite effective research studies in the National Academy of Sciences, which identified the next generation facilities and the important research targets. This engineering research study which was mentioned that is now ongoing in the Academy is a reflection, as a matter of fact, of what some of us in the engineering community have said should be done of a comparable nature to what had been done in astronomy, and in chemistry, and in physics in previous years.

So I'm not so worried about the future role of engineering inside the NSF with respect to the sciences, because I think we have our act in better order on the engineering community side. I think we're going to speak out and speak out vigorously for needs in engineering, and I suspect that we'll find a good, continuing balance there.

Mr. **Brown**. Well, I'm not particularly concerned at the present time. I think the atmosphere is good there, and I commend the Academy.

I've always commended the National Science Foundation for what they are doing, but what happens over there occasionally is that you get domination by a spirit which is similar to what Lord Rutherford used to have. He didn't believe in anything that had any practical application of any sort. He might get interested in designing better physics instruments but not anything that had to do with anything beyond that. In fact, he thought it was positively bad for a physicist to get involved with anything that had application.

And if that attitude gets into the National Science Foundation, particularly at the top levels, it tends to slight anything like engineering which might have broader societal implications. That's the thing that's to be feared in the long run, not the present situation so much. But you're not concerned about that?

Dr. **Drew**. No. As I say, I think the key corrective force is going to be an aware, an involved engineering community. If indeed that point of view should come into dominance in the NSF, I suspect that we'll have no one to blame but ourselves in the engineering community.

Mr. **Brown**. I'm going to turn the chair over to the chairman of the subcommittee at this point, Mr. Walgren, and if he has questions, then he can use his discretion as to how long he wants to take.

Mr. **Walgren**. Thank you, Mr. Brown. We appreciate the time you've been able to give this morning.

I just wanted to ask again—the resistance or the opposition to transferring the functions of the National Science Foundation's Engineering Directorate to any proposed National Technology Foundation. Is there a substantial split on that opinion in your organization in view of the thought that a separate engineering function with respect to the foundation would be very helpful from an engineering standpoint?

Dr. **Drew**. Mr. Walgren, I think probably the contrary is true, that the general, very strong opinion that I've heard from many levels within the IEEE is strongly in favor of maintaining and strengthening the engineering research function within the NSF and therefore basically retaining it there.

The National Technology Foundation, in this particular approach that I've suggested, largely works in an area which is complementary to that role rather than in parallel with it, and I view that as being a quite appropriate division of labor in this sense. When I said the transfer of engineering, I really meant that there was support of engineering research. There may be some other pieces that would be appropriate to the National Technology Foundation.

There certainly is the support, say, for the Small Business Innovation Research Act and similar functions which might very well better belong in the National Technology Foundation than elsewhere, but this is a detail of organizational structure which I think is less important than the general premise, which is, the support of research should stay as part of a strong NSF; yes.

Mr. WALGREN. You're very comfortable with the engineering research function staying within an integrated NSF?

Dr. DREW. Yes, indeed.

Mr. WALGREN. I see.

Dr. DREW. But we don't think that negates the importance and utility of a National Technology Foundation. I think we want to try and stress that point—that there is a different set of roles here.

Mr. WALGREN. Yes. It's so difficult on a political level to decide or gather the necessary support for any particular economic effort on the part of the Government. The people who say, "Look; stay out; leave it to the marketplace; the marketplace should drive it, or it shouldn't be driven," it seems to me, have such an advantage over the other side of the spectrum that says, "Well, there's possibly a role for the Government in this area but not that area," because if you don't agree on which area, at that point, that viewpoint is essentially divided, whereas the other remains whole.

I noticed in your testimony, you feel comfortable limiting the Federal role to essentially longer term research and development.

Dr. DREW. And to attention to the incentive structure which applies to industry. I mean there's an information function, there's a sort of linkage of the type of long-term R&D that is represented by the NASA or previous to that, by the NACA role in aeronautical research, that can quite conceivably be a part of this or would be a part of this National Technology Foundation.

The area of manufacturing technology was mentioned here, and the fact that there wasn't an appropriate Federal climate to support that.

Well, it's interesting that at least 10 years ago in the NSF, there was a manufacturing technology program, but it was a program which struggled for its existence, budget season by budget season, in an institution that was not oriented to this type of activity. I know this because I was part of the NSF during that period, and I, in fact, tried to nurture that small piece of the NSF, because even then it was very clear that this was a growing and urgent area of national need.

Mr. WALGREN. But——

Dr. DREW. But we didn't have the right institutional structure to nurture and build that in NSF.

Mr. **Walgren**. Yes.

Dr. **Drew**. And at NTF, you would.

Mr. **Walgren**. Would the lack of that right institutional structure reflect my guess that that was an activity that was being done almost around the edges, without direct focused political support from the political directing agencies of the Government, and in fact had it come to rise to the level of visibility in the NSF to the point where the Republicans and Democrats started to tear it apart, it probably wouldn't have been able to survive? Would that be an unfair characterization?

Dr. **Drew**. Mr. Chairman, I guess I've never viewed, at least to a very large extent, the NSF's programs as being subject to partisan pulling and tugging.

Mr. **Walgren**. But we've had some very partisan pulling and tugging in the last couple of years.

Dr. **Drew**. Looking at it from the NSF's standpoint, I would guess the programs never were viewed as somehow or other responding to a partisan viewpoint but indeed responding to some sense of national need.

It's quite possible that if the program grows and it becomes much more visible and it doesn't quite match the then-political philosophy of whatever administration exists at that time, it could be in trouble. But for the most part, we're talking about technologies which have much longer term horizons—and I would hope would not be subject to that type of partisanship.

Mr. **Walgren**. Well, I guess I'm just trying to satisfy myself about—the underlying rationale that is supportable from your point of view and the point of view of others in this area of picking winners and losers. You indicate that you would be reluctant to see the Federal Government get involved in areas of declining industries, that the marketplace is signaling that they are truly declining, and yet I don't know how we, on a political level, make those judgments. If we could fasten on the idea that we are willing to substantially support research and development in any major area of major economic consequences, perhaps that would find enough support in the country at this point to provide some necessary ability to make progress in declining industries like steel and others.

Dr. **Drew**. It's not the research or the long-term technology development, I think, that we have a problem with. It is perhaps the next step, which then takes that and somehow or other artificially shores up the industry through further direct financing and intervention.

Providing the right incentive structure, providing support in areas where the current market does have some defects—and I would say that's in the longer term research and technology applications arena—would provide tools and would provide things which such declining industries could grasp and perhaps introduce into their production processes that would give them a new lease on life.

But at the point of actually financing that, I think we really have some reluctance to see the Government—Chrysler and Lockheed notwithstanding—getting into that on a regular basis. I think there are some circumstances—clearly, there have been some interesting articles written recently pointing to the Lockheed, Chrysler, New York City bailouts, if you will, as appropriate uses of Federal support.

The circumstances under which Federal support was granted were very special in each case, and it seems to me you would not want to establish an institution that had that as a regular, assigned role going around looking for places to shore up.

I think it would be better played out on an ad hoc basis for really situations where you felt a national need and that may be a national security need. You can't allow the last steel plant to go out of production in the United States, clearly, for some very important national security reasons. You can't let the last forging plant or the last machine tool industry to go out of business.

So, there are some points at which the Federal intervention does make sense. We just don't see this done on the basis of some investment bank which has a continuing rolling fund to do this.

Mr. **WALGREN**. It just strikes me that perhaps if we had a broader consensus on the importance of the initial health of the research side, that maybe we wouldn't find ourselves in such desperate straits that we need to reach for either the bailouts or the major bank decisions from Government.

We have the Commerce Department doing a little bit of metals work around the edges, but they are already doing it when Congressmen from Pennsylvania find out about it.

That seems to me to be a measure of the fact that they could see the handwriting on the wall and knew that this was a reasonable function and had some discretionary funds available, but that was really about it in terms of the commitment of the Federal Government. It would seem if we had gotten in that area with both feet earlier on, we might not then be driven to get into the——

Dr. **DREW**. The bailouts.

Mr. **WALGREN**. The bailout-type involvements with both feet later on.

Dr. **DREW**. Yes, indeed.

Mr. **WALGREN**. Mr. Gregg.

Mr. **GREGG**. Thank you, Mr. Chairman.

Dr. Drew, can you explain to me, or give me a couple of examples—I'm willing to accept the long-term, high-risk approach as being a proper Federal role, but give me a couple of examples of where this National Technology Foundation—specific examples of programs that you would see them getting in—having—getting in, if the Federal role were created.

Dr. **DREW**. One of the areas, Mr. Gregg, is, I think, a much more vigorous implementation of the Stevenson-Wydler Act, the provisions of which include a series of cooperative generic technology centers.

Now, there have been a few of those that have been generated under the auspices of the National Science Foundation. I think that's a reflection of the fact that they can be and are a useful part of the industrial scene. They bring Government in a kind of incentive structure that brings industry and universities together. I would view that as being an area that could be expanded considerably.

I think there were in the Department of Commerce's initial proposal for implementation of Stevenson-Wydler a series of such centers, most of which have never gotten off the ground. So I would see that as one area in which this new institution would operate.

I mentioned the Federal Industrial Extension Service, which is in one of the companion pieces of legislation. I think that is a highly useful and valuable service that should be started and permitted to grow and provide the technology services to——

Mr. GREGG. Can you explain——

Dr. DREW [continuing]. Small business.

Mr. GREGG. Can you explain to me what you conceive the Federal Industrial Extension Service to be doing? What would they do on the street? A small—give me an example. What knowledge, what abilities would they deliver to a small business?

Dr. DREW. Well, a small business has lots of problems. Some of the problems are financial, basically, "How do I locate my next increment of capitalization?" The assistance in developing contacts with that risk capital marketplace would be one type of service.

Another is assistance in financial management inside the company—in other words, providing a financial troubleshooter the company to deal with overhead rates that are getting out of control or inventories that are not being managed properly, and so on.

I mean these types of assistance that can help the institution in——

Mr. GREGG. If you could stop there——

Dr. DREW [continuing]. Small business in just running its business.

Mr. GREGG. Do you think it's a proper role for the Federal Government to have somebody on the street available to give that sort of assistance to the small business?

Dr. DREW. I think that, yes, it runs very much like the kind of assistance which is provided in the agricultural field to the small farmer.

I mean basically the small businessman and the farmer I would view as an important part of the foundation stones for our economy. This isn't free, by the way. You'd pay for those services. But having the institutional structure that you could call upon, a place to go, if you will, to bring the expertise to bear on your problems is what's important.

There is a sort of R&D linkage——

Mr. GREGG. That role is presently taken up by the Chamber, the local bank, local accountant, the local lawyer, but you don't think they're doing an adequate job? You don't think the free market's adequately addressing the ability of small businessman to get rolling on his own? You think the Federal Government needs to be out there aggressively seeking out the small businessman and giving the great knowledge which the Federal Government has absorbed over so many years in the private sector?

Dr. DREW. Those are your words, of course, about the Federal Government's great knowledge. I don't view this as being the Federal Government's great knowledge that's being shared but providing linkages to places where the knowledge does exist. What I'm suggesting is, no, that the existing private marketplace, while it provides some of those functions, is not providing those completely and adequately at the present time.

There is a technology function as well.

Mr. **Gregg**. Well, let me stop you there. If we follow that logic forward and we compare this to the Farm Agricultural Cooperative Extension Service, which I think does a pretty good job in the farm communities, I suppose then we're also going to have to follow the logic forward which delivers us a farm bill on the floor of the House every year, which this year represents a subsidy to the farmers which exceeds the net income of the farm industry in this country.

So we are going to move into the private sector, and take over, and subsidize that industry, and we'll have subsidized small businessmen dealing with subsidized intermediaries. Is that the concept that flows from this logically?

Dr. **Drew**. I don't see that as being necessarily the logical followup. As a matter of fact, I suspect that the farm subsidies, it turns out, subsidize the large producer, the very large farmer, and not the small farmer.

You know, the small family farm, of course, is a very small fraction of the total agricultural production base in the United States, and for the most part I think these major subsidy bills in agriculture benefit the very large producers.

The equivalent would be benefits to the GE's and IBM's and maybe AT&T's. If that was an outcome, I would guess it's certainly not what I would foresee as the result of providing this Extension Service.

Mr. **Gregg**. The farm industry in this country—and it's going to come as a surprise, I think, to my small farmers—the milk farmers that are not subsidized—but the farm industry in this country is the most centralized—centrally managed, quote, "free market enterprise" that this country has. It's managed right here in Washington. All the prices are set in Washington. Whether you till your field or don't till your field is decided here in Washington. Whether you put your cow and milk it, or whether you cull your cow is decided here in Washington by the rates that we set. I see almost no comparison between the farm industry and open market.

Now I don't want to beat a dead horse, to pick a phrase that comes out of the farm industry, but for the Federal Government to get into the business of trying to promote small business, I think, is—they are antithetical entities.

To move to another issue, you have already existing in the National Science Foundation, as you mentioned, the engineering directorate; plus, you have in the Commerce Department the responsibility for Stevenson-Wydler.

You're talking about taking all of these various functions—and I recognize your agency thinks engineering should stay in NSF—and merging them into one new operating entity which will basically be a new National Science Foundation, only it will be a step up from research.

Yet, as I understand the bill, we're not talking about creating any new funds for this agency. We're talking about taking the present funding levels and moving them all into this new agency with the transferred organizations.

If that's the case, why should we go through this whole restructuring scheme? Why shouldn't we let Commerce do its job with the funds it has if we're not adding new funds? Is it so important that we pull these agencies out and just reshuffle them? Is this really that essential?

Dr. DREW. We are supporting this as, we believe, a positive step, and you say is it that essential? The implication—and to go back to my opening remarks—is that by restructuring that, they are not functioning as well as they might in their current homes, and I think that's that a point that I made. I said, with all due respect to the individuals and the efforts within the Department of Commerce and elsewhere, that there is not a particularly receptive and positive home for these functions.

As a consequence, the budgets have been really extremely bare bones. They've just managed barely to survive.

We believe that an important positive benefit will result from bringing them into a structure which has these objectives as its principal role, rather than burying it within a department which is, for the most part, not terribly aware or very interested in these functions.

Mr. GREGG. I think that may make some significant sense, but once you've created this new entity—this new National Science Foundation—National Technology Foundation, as it will be called, how do you keep it in its ballpark?

How do you keep it from not becoming the agency which decides to start funding commercial technology, which is short-term, as versus long-term, which is commercially competitive?

How do you keep it from not becoming now the "super decider" of what the marketplace wants and desires and making the outrageous decisions which the National Science Foundation found itself making when it decided to get into this area and the Department of Energy found it making when it decided to get into commercialization areas?

How do you circumscribe its activities so it sticks with long-risk, high-term commercialization and sticks to the projects which are being pulled out of these various agencies?

Dr. DREW. Well, first, I would say you craft its legislative mandate very carefully. In other words, you try to provide in the language of the bill the kind of guidelines that will, first of all, start it off operating in the proper domain, and clearly define that domain.

The second part is, of course, the Congress. An alert Congress presumably is going to, number one, be able to restrict in either appropriations or in other language the kind of functioning that they thought was getting out of hand or getting into areas that it would be inappropriate. Indeed it seems to me that's the job that you've being doing for a couple of hundred years now, and I would——

Mr. GREGG. Extremely poor, I would note.

Dr. DREW. Well——

Mr. GREGG. We're usually there about 6 days after the horses have left the barn.

Do you think this agency—this new group—this National Technology Foundation, or the ATF, should have the ability to make direct grants into the private sector for the purposes of creating commercial products?

Dr. **Drew**. No. No. We absolutely suggested that was an inappropriate function, and we pointed out that we would see that as being one of the parts of the legislative mandate that should be removed.

Mr. **Gregg**. At what point should this agency be allowed to make a direct grant? Can you give me both theoretical, and then specific areas where direct grants should be able to be available under this agency into the private sector?

Dr. **Drew**. Well, let me point out that one of the provisions which is in the ATF has to do with this development of, if you will, a lending provision, which would be quite comparable to the NRDC in the United Kingdom and to this BIRD Foundation which the United States is already supporting. That is a process whereby proposals come in, they are evaluated. It's a little bit different from a direct grant. Funding is provided for research which will eventually lead to a product.

The product that is determined by the company or companies that are involved, and the product that is produced then, with the profit that is obtained, would return funds, by a formula, to the original fund.

Mr. **Gregg**. What would be the bottom line, if you can just give it to me conceptually, of what type of application would be reviewed? In other words, would the applications be directed at putting a product on the shelves? Would they be directed at doing long-term research? What would be the review standard?

Dr. **Drew**. It's restricted to research. I guess I could point out a product that we're working on right now, for example. It's an example that would seem to me would be quite appropriate.

Basically, we're working with a technology that was originally developed by the National Aeronautics and Space Administration—NASA. I would expect this is the kind of thing that the Center for the Utilization of Federal Technology is supposed to be doing. We became aware of this technology, became interested in it as leading to a commercial product.

But the NASA technology was so gold plated that it clearly would not be a commercializable product the way it was. We are in the midst of investing additional funds—and this is a somewhat longer-term venture than the typical industrial product and investment cycle—to bring forward that technology which was supported by Federal funds, but was, until we picked it up, was sitting on the shelf. We asked for and received an exclusive license for it. We're bringing it into a commercial product line.

In fact, we are doing the kind of longer term research and technology development that I would see fitting within this mode of operation.

Mr. **Gregg**. And I presume you're financing it in the private sector at the present time.

Dr. **Drew**. We're receiving support under Public Law 97-219, I believe it is, the Small Business Innovation Research Act, and without that, we would not be where we are today. This project would still be a gleam in our eye but not an ongoing technology development.

Mr. **Gregg**. It's nice to know that we do have that law already on the books, but aren't we going to, under this proposal, attract into the application process those programs which are the bottom priorities of the businesses that are coming in?

I mean if they know that they've got a chance of making money, they're going to find the money. Aren't you really going to just be picking up the really low priority program as the applicant here, within that own business' estimate of what's going to make money and what's not going to make money?

Dr. **Drew**. Well, you said low priority. Let me suggest to you, look at it quite a little differently, and that is, any business has a variety of places that they can put their investments.

The current dynamic within a business is, you take a look at those investments which are going to provide the quickest turnaround, the shortest return on investment that you can, and those are your highest priority.

Now, these other investments that are going to have a longer term payout you've characterized as being the bottom of the barrel or the lower priority; I would characterize as those not necessarily in that way——

Mr. **Gregg**. No, that's not——

Dr. **Drew**. They are not being chosen and are not being supported because they have this characteristic of having a longer term payout. What we're doing here is providing an opportunity for some of those high priority investments to come on line much more quickly.

Mr. **Gregg**. Well, what we're really doing is we're taking the high priority investment that we know that a company can look at and say, "Well, we're going to get a good return on high priority investment, so we're going to invest our capital in that investment," and they've maybe got 10 high priority long-term investments.

The short-term, quick return investment, that's going to be done in the private sector. And they're going to say, "Well, we're going to pick up the private sector money to do those." And then for this marginal number, 28, that's going to take the same time as the other ones—"Well, let's take a run at the Federal dollars for that one; we don't think there are going to be much of a return on it; it's obviously not going to have the return of the other ones we've prioritized ahead of it, but let's take a run at it because there are some Federal dollars," and then the Federal dollars that are being used are tax dollars. They're perverting the marketplace, because you're taking Federal dollars which are going to be used to fund that 28th project out of the taxpayer—out of the private sector, and you're funding that 28th project.

If you'd left that Federal dollar in the taxpayers' hands, invested in the private sector, another company would have used it to fund their No. 1 project. And you have perverted the flow of capital in the marketplace, that's what this national policy does. It totally perverts the national marketplace, because it makes the Federal Government the decision process as to where capital will flow, and inevitably the Federal Government is going to pick lower priority items because the nature of the institution is such that it does that.

Dr. **Drew**. I would suggest, Mr. Gregg, that whatever the Federal Government would be prepared to do here is a small wart on this very large establishment which is the private marketplace. You're not going to skew that private marketplace very much, and——

Mr. **Gregg**. Well, don't tell that——

Dr. **Drew** [continuing]. Not with any of the funds that you're talking about on this scale.

Mr. **Gregg**. Dr. Drew, don't tell that to the person who's out there trying to borrow moneys today and is paying the highest real interest rates they've paid in history because we're running a $180 billion deficit.

The Federal marketplace is perverting the private marketplace, and it's perverting the world marketplace, and it's one—you know, it's a million here, a million there, and adds up to a billion here, a billion there, which adds up to real money, as——

Mr. **Walgren**. The gentleman's time has expired.

Mr. **Gregg**. Senator Dirksen used to say, and I recognize my time is expired, and I appreciate the chairman's indulgence.

Mr. **Walgren**. And we'll give the witness an opportunity to respond.

There are a lot of reservations that I know we can all express and probably better someplace other than the record, but Mr. Drew, please, if there's something you'd like to add, please go ahead, and then we ought to get on to the next witness.

Dr. **Drew**. I would just like to thank the chairman for the opportunity to present our views, and I'd say we'd be very happy to continue the dialog on this subject. I think it's an important one. It's one on which people can have quite different and valid opinions or outlook. We certainly think it's an important area for us to try to provide more light in an area where our understandings, I think, are still growing and developing.

Mr. **Walgren**. Well, we thank you very much for coming, and we appreciate your being a resource to the committee. Thank you, Dr. Drew.

Dr. **Drew**. Thank you.

Mr. **Walgren**. The last witness for today is Donald Weinert, the Executive Director of the National Society of Professional Engineers.

Welcome to the committee, Dr. Weinert.

Mr. **Weinert**. Thank you.

Mr. **Walgren**. We appreciate your coming, and know that your written statement will be made part of the record. Please feel free to communicate to the committee the points that you feel are most worth stressing in any way that you feel comfortable. Thank you.

STATEMENT OF DONALD G. WEINERT, EXECUTIVE DIRECTOR, NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS

Mr. **Weinert**. Thanks very much, Mr. Chairman and members of the committee. It's a real pleasure for me to be here to give some of our views, and I'm just going to hit a few of the highlights of some of the points made in my written testimony.

We appreciate the role that your subcommittee is playing in this debate. As you know, we've been involved in this debate on technological innovation for many years, and, as we've already seen, there are many dimensions to that debate.

I think that one of the points I would like to make at the outset in setting the stage is that while there are lots of good things about our system—and we've all alluded to those—none of us pretend that it's perfect, and we would be foolish not to reexamine our institutions and our policies on a regular basis to see if, in the light of changing political and economic circumstances, some kind of modification is necessary, and I think this process is a part of that reexamination.

We can't automatically assume any more that "Just because it's American, it's going to be No. 1 in the world." We're not in that position any longer.

The whole business of technological and industrial competitiveness has two major elements, as we see it in the engineering community; first of all, invention, the process of innovation that develops new products and processes, new ideas, and then, secondly, and equally important, this attention to quality and productivity that means we do things in better and more efficient ways.

We think that for both of these elements, the primary responsibility is really in the private sector, and I think that probably sums up the feelings of the National Society of Professional Engineers as regards the basic Federal role.

We think there is a Federal role, and we think it's an important one. We think it is most importantly focused on the right environment for the private sector to carry out its basic and fundamental responsibilities.

John Young was here last week testifying, and I had an opportunity to look at his recipe for industrial success. It was quite interesting to note that really what it was was a manual for good management rather than a prescription for massive Federal action.

He pointed out, the most effective mechanisms a government can use are those that foster innovation through maximizing private sector resources, and I think we agree with that philosophy in the National Society of Professional Engineers.

There are several proposals, if you will, talking about the environment for research and innovation, that everyone pretty well agrees on.

We all pretty well agree that the R&D tax credit needs to be made permanent or extended; we all agree something needs to be done with the antitrust laws to permit cooperative R&D in certain instances; we all pretty well agree that the various proposals floating around to make capital more accessible to business are worthwhile and we ought to continue to pursue those; and we all agree that the Government needs to pay attention to the business of the education of technical manpower, the support of that educational process by ensuring a healthy science and engineering educational base, or helping to ensure that.

We need to get on with those measures. Those are part of creating the right environment.

However, it's less clear just how far the Government ought to go in direct intervention, direct involvement in promoting innovation and the innovation process.

Now, I'd like to just comment briefly on the several pieces of legislation in that connection because most of them envision a more direct Government role.

First of all, we see H.R. 4361 that calls for an Advanced Technology Foundation as an overlay on the existing system rather than a substitute for anything in the existing system.

Now, that overlay doesn't seem to us to hold any real promise for getting things done any better or more effectively than our current institutions that exist in Commerce, the National Science Foundation, and several other places.

We see a lot of problems with an overlay agency like the Advanced Technology Foundation. First of all, it seems to be focused on our strength rather than our weakness. We're the most inventive Nation in the world by any measure—any standard that you care to choose—and any failures we've had in converting this inventiveness into usable products and processes have more been management failures, economic factors, and restrictive Government policies than they have been any kind of a failure in our technological ability.

While there's no question that $500 million invested in advanced research, as envisioned by the Advanced Technology Foundation, is bound to produce some valuable results, it isn't going to address the roots of our competitive problems.

And, further, if you look around to the constituencies who would be most supportive of this type of a proposal—the business and education R&D community—you don't see any groundswell of enthusiasm or support for the concept of the ATF, and they're the ones that are most likely to directly benefit, if there were an ATF.

In short, we don't see any well-defined mandate for H.R. 4361, for an overlay Advanced Technology Foundation, and we don't see any real gap in our present structure that it would fill.

Now, H.R. 4361 does have an element, that Dr. Drew mentioned, that we would also like to support. That's the business of promoting the diffusion of technological information, not so much business information, as the discussion that was held a little earlier—Mr. Gregg with Dr. Drew.

We think that an extension service to disseminate technological information about generic technological processes and knowledge to the States and to business would be very valuable in the same vein as an Agricultural Extension Service, but focused on dissemination of technological information.

Now there happens to be a law already on the books, the State Technical Services Act, enacted in 1965, that would really permit this, and we would advocate that if we want to do this, and we think it's a good idea, that we look to existing statutes. That was last funded in 1971 and zeroed out after that. We think the mechanism is there in existing statutes to do this diffusion process.

Another bill, H.R. 1243, calls for a means to gather and analyze competitiveness—the competitiveness of various industries. We think we already have this capability in the Office of Competitive Assessment in the Department of Commerce.

Now maybe we haven't paid enough attention to it. Maybe it hasn't been effective, for a variety of reasons. We think, let's make it effective; let's better fund it; let's make it more visible; let's make it more available; but let's not supersede it.

We think also that if we are looking for studies of competitiveness in various industries, that we also have the National Research

Council under the guidance of either mean the National Academy of Sciences or the National Academy of Engineering, to conduct studies, and they have done some excellent work.

As a matter of fact, if you look carefully at the study issue, there is another bill, H.R. 2525, that's proposing sort of an omnibus study of the U.S. technological posture. We think the Young Commission is already engaged in that process, and we ought to see what comes out of it before we run off into another study of our technological posture as proposed by H.R. 2525.

Now we think in H.R. 4415, the Manufacturing Sciences and Technology Research and Development Act, there is something very worthwhile—the idea of creating research centers that focus on cross-cutting process-oriented work—incidentally, not unlike the centers proposed in the COGENT program now authorized but not funded under the Stevenson-Wydler Act.

The Centers for Cross-Disciplinary Engineering Research now being proposed by the National Science Foundation, by the way, are also very similar in nature to this.

Whichever form we pursue, we think centers that can respond to well-defined generic research needs that have broad industrial applicability and broad industrial involvement are worthwhile.

We would like to focus on the NSF—the National Science Foundation program. It's in being. We think it can be promoted to accomplish the purposes of these generic cross-disciplinary research centers, which we think are an important partnership between education, industry, and government. Again, existing authorities would permit us to do this without going ahead with H.R. 4415.

Now if we look at H.R. 481, the National Technology Foundation, we can see a lot of attractive features. There is always a certain compelling interest in organizing things better and bringing them together, and we see that same type of attractiveness.

However, we really can't see a compelling case for the tremendous costs and dislocations that would inevitably result in creating a new foundation, particularly in light of the direction we're currently taking with the National Science Foundation to expand its role in the engineering area, and, as a matter of fact, I see some dangers in creating a National Technology Foundation while, at the same time, we're trying to promote the partnership between science and engineering in the National Science Foundation.

We feel that partnership is very important. You really shouldn't separate engineering and technology from science. They need to work together. There is a big gray overlap area between the two, and we think keeping it all together in the National Science Foundation in the R&D and support for education area is a much wiser course than splitting it off into an independent foundation.

We look to the NSF with the leadership of this subcommittee, by the way, to provide the focus of basic and fundamental research in education for both science and engineering, and in recent months, by the way, the NSF has demonstrated not only its interest in doing this but its willingness to move in this direction. All it needs is the authority and the resources.

And I'd like to make a very important parenthetical statement at this point. We in the engineering community feel very strongly that as this new partner comes on board—engineering and technology in the National Science Foundation—we must not degrade the capabilities of the longstanding established existing partner, basic scientific research.

We have to find the resources to expand the role and support of engineering and engineering education without taking money away, and resources away, from basic scientific research, which is extremely important, and we, again, feel that those two things work very, very closely together.

Again, I mentioned before the cross-disciplinary centers in NSF. We think they're very important, and we think that's an example of the kind of program where NSF can promote needed research in our educational institutions which, at the same time, happens to have the added benefit of training engineers in practical, problem-solving work, the kind of training and education that they really need. It accomplishes both purposes.

We urge you to continue to encourage NSF to foster not only premier science but excellence in engineering.

I guess, in conclusion, I could say that we feel that we have in place most of the authorities and the institutions necessary to deal with the Government role—the Federal role in support of innovation, inventiveness, industrial competitiveness, and we think that role is to foster the right environment and to use direct measures only when those direct measures can maximize the availability and the capabilities of private sector resources.

And we again commend this subcommittee for its initiatives with the National Science Foundation to modify its charter and move it in the direction that we think is so important.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Weinert follows:]

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TESTIMONY OF
DONALD G. WEINERT, P.E.
ON BEHALF OF THE
NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS
ON
FEDERAL ORGANIZATION
FOR
TECHNOLOGICAL INNOVATION
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
JUNE 12, 1984

Good Morning, Mr. Chairman, Members of the Subcommittee. I am Donald G. Weinert, P.E., Executive Director of the National Society of Professional Engineers (NSPE), which I represent here today.

NSPE is a non-technical professional society, representing over 80,000 engineer members nationwide. Our members are organized into 54 state societies and over 500 local chapters, and work in industry, private practice, government, construction and education.

We are pleased to have this opportunity to express our views on the Federal role in technological innovation. For several years now, we have participated in the evolution of the "innovation" debate, and appreciate the contribution this Subcommittee is making. Clearly, if the United States is to maintain world leadership in technology markets, we must re-examine our policies in light of changing economic and political circumstances. We can no longer afford to assume that technological pre-eminence is automatically American.

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Technological and industrial competitiveness depends on the pursuit of two distinct lines of endeavor. On one hand, invention and innovation assures that we will make new, improved products and services. Attention to quality and productivity, on the other hand, assures that we will make these things in better, more efficient ways. We believe the primary responsibility for these activities lies within the private sector, not in government. Government's responsibility is to provide the right environment. In testimony presented to this Subcommittee just last week, John Young, President of Hewlett-Packard, outlined a recipe for industrial success. Mr. Young's recipe consisted of a manual for good management, not a prescription for Federal action. As he pointed out, the most effective mechanisms the government can use to foster innovation are those which maximize private sector resources.

There appears to be fairly universal agreement that proposals to make permanent the R&D tax credit, to revise antitrust laws to permit joint R&D ventures, to foster availability of capital and to support the education of technical manpower are all desirable government activities that would help maximize private sector resources. It is less clear, however, whether government should get more directly involved in the business of promoting invention, innovation, and productivity improvement. On this point we urge caution.

The several pieces of legislation now before this Subcommittee provide an excellent opportunity for discussion. H.R. 4361 calls for an Advanced Technology Foundation that would put government directly into the invention/innovation business by selecting specific near-market technologies for investment. We see several problems with this. It seems to be an attempt to cure our strength, not our weakness. We are the most inventive nation in the world. Our failures to capitalize on this in certain industries has more to do with management failures, economic factors and restrictive government policies than it does with our technological abilities. While investing another $500 million in "advanced research" as called for in H.R. 4361 will undoubtedly produce some valuable results, it will not address the roots of our competitive problems. Furthermore, constituencies one would expect to benefit from the ATF, the business and university R&D leaders, have yet to express any broad consensus of enthusiasm for this idea. In fact, our experience indicates that advanced research can best be fostered by free market forces, except perhaps in selected defense and environmental areas.

Further, we do not find H.R. 4361 responding to a well-defined mandate, nor does there appear to be any gap in our present structure that would be filled by establishing this Foundation. It seems unlikely that a new agency will be better equipped to determine unmet needs in advanced technology than the private sector itself.

H.R. 4361 does have what we believe to be an extremely important element - that of promoting the diffusion of technical information. However, we suggest that rather than create a new bureaucracy for this purpose, the Subcommittee consider the State Technical Services Act, enacted in 1965 and funded until 1972, when it was zeroed out of the budget. This law is still on the books and, if funded, could be used to disseminate technical information to the states, in the manner of the "extension service" that has proven so successful in agriculture. We would be pleased to provide additional information on this program if the Subcommittee would like to further pursue it.

Another bill, H.R. 1243, calls for a new means to gather data and analyze the competitiveness of various industries. We already have this capability through the Office of Competitive Assessment in the Department of Commerce. This office has done excellent analyses of the petrochemical, telecommunications, and civil aircraft industries. We believe it should be better funded, more visible and more available, but certainly not superceded. The National Research Council, too, does an outstanding job of studying various technological problems and recommending solutions. Further, the President's Commission on Industrial Competitiveness is conducting the indepth assessment of the U.S. technological posture as proposed by H.R. 2525. In sum, we urge the Subcommittee to examine existing structures and statutes to accomplish the objectives posed by these bills.

A potentially beneficial Federal initiative lies in H.R. 4415, The Manufacturing Sciences and Technology Research and Development Act. This bill provides a mechanism to create centers for manufacturing research and technology utilization, which essentially are research centers that focus on cross-cutting, process-oriented work, similar to the COGENT program authorized but not funded under Stevenson-Wydler. The Centers for Cross-disciplinary Engineering Research now proposed by NSF are also similar. In whichever form you choose, these centers all have the ability to respond to specific, well-defined research needs, with broad industrial applicability and involvement. We are particularly supportive of the new NSF pogram, which provides a means to both accomplish needed research and train new talent using current, practical engineering problems. Engineering education needs more of this type of experience to best prepare engineers for professional practice. Once again, existing agencies and authorities can accomplish the aims of H.R. 4415.

While we applaud the objectives of H.R. 481, the National Technology Foundation, we do not believe there is a compelling case to create a new foundation to meet those objectives. True, creating an NTF would coalesce technology and engineering functions in the Federal structure, and in doing so might focus more public and political attention on their importance. However, given the fiscal realities of federal budgets and the organizational realities of new federal bureaucracies, we do not believe the enormous resulting costs and dislocations are justified. Rather, with the initiative of this committee, the engineering community is looking to the National Science Foundation to serve as the focus of basic and fundamental research and education for both science and engineering. We believe science and engineering must remain close partners and that engineering and technology must not be separated into a new agency. In recent months, NSF has demonstrated that while preserving its excellence and integrity in basic science, it can and should serve equally well for engineering. We applaud this direction, and urge its continued growth. The cross-disciplinary centers are one example of NSF's potential to support emerging, interdisciplinary research areas that deal with systems, processes, methods and materials. We hope programs of this type will expand, and in doing so strengthen the Foundation. The Subcommittee has recognized this important role for the NSF with your approval of an amendment to the NSF charter to enhance NSF's commitment to engineering. We urge you to continue to encourage NSF to foster not only premier science, but also excellence in engineering.

In conclusion, we believe that by creating a climate in which invention, innovation, productivity and quality can thrive, the government can then use more direct mechanisms such as NSF most effectively. In this environment, our outstanding base of science and education can lead us to excellence and leadership in technology.

NSPE BIOGRAPHY OF EXECUTIVE DIRECTOR

DONALD G. WEINERT, P.E.

Donald G. Weinert, P.E., was appointed Executive Director of the 80,000-member National Society of Professional Engineers (NSPE) on September 1, 1978, following a highly successful military career in which he attained the rank of Brigadier General.

Prior to assuming his position with the Society, Mr. Weinert held several prominent positions with the Army Corps of Engineers, including Special Assistant to the Chief, with responsibility for establishing and managing an accelerated pollution abatement program for the Army, and as chairman of the Department of the Army's Ad Hoc Study Group, which investigated ways of improving operation and maintenance of Army facilities. Domestically, military assignments involved planning, design and construction management experience in water resource development in California and Arkansas. Foreign service included tours in Germany, Korea, and Vietnam.

A number of distinguished honors capped Mr. Weinert's military career, including three awards of the Legion of Merit, a Meritorious Service Medal, two Bronze Stars and four Army Commendation Medals.

A graduate of the U.S. Military Academy at West Point, Mr. Weinert received his Masters in Engineering from Purdue University, attended the U.S. Army War College and has participated in the Army's Advanced Management Training Program at Northwestern University. Prior to assuming the position of Executive Director, he served on both the Professional Schools Committee and the Ethics Task Force for NSPE. His Professional Engineer registration is in the State of Texas.

Born in Aberdeen, South Dakota, Mr. Weinert, his wife Suzi and their five children now reside in McLean, Virginia. He has been extensively involved with Little League and Boy Scouts of America activities.

Mr. **Walgren**. Well, thank you very much, Mr. Weinert.

You emphasized the importance of the cross-disciplinary centers and the generic technology centers under the Stevenson-Wydler and the information services, and as I understand it, perhaps after we had the State services that you referred to, we have the National Technical Information Service, which certainly from its title has a charter directly on point, and yet you are hit right between the eyes by the fact that we have done nothing, literally nothing with those agencies. Stevenson-Wydler wasn't even picked up; the NTIS is funded with partially amount of money. The information related to the Japanese technology information effort turned out to be one man in Tokyo, or something like that, that was eating up half of their allocated budget in salary alone. It's just nonexistent.

Given your recognition of how important those functions are, why do you think we find ourselves at this point in 1984 having reached almost a crisis point in some of the areas, where we believe these functions would have made a contribution, with no effort?

Mr. **Weinert**. Well, you've asked really two questions. One has to do with the cross-disciplinary centers, and the other has to do with the information service.

Mr. **Walgren**. My purpose is to say that you've stressed all these functions, none of which have had any government effort, even though we have a structure that has been put there but not used, and the question is why, in these areas, which you have put great emphasis on, have we not used any of them that we now feel we need to point to as existing?

Mr. **Weinert**. On the first point, the cross-disciplinary centers, I think we have recognized that that's important and are now putting a great deal of emphasis through the National Science Foundation Cross-Disciplinary Centers.

It doesn't make any difference whether it's a Stevenson-Wydler COGENT—whether it's an NSF Cross-Disciplinary Center or whether it's a H.R. 4415 center, they're all aimed at the same thing.

I think we've focused on the right one—the National Science Foundation Cross-Disciplinary Centers, which are now being funded, with the wisdom of the Congress and the support of this subcommittee and many others in the Congress, and I think that we will continue to put emphasis on those.

Why we waited this long, why we didn't do something when Stevenson-Wydler passed, I can't really answer that question, but I can say that we now recognize the importance and are doing something under an existing institution to deal with that problem.

Now on the information dissemination, that's a much more difficult question. I am not familiar with what went on in the Congress back in 1972 when, I am told, for largely political reasons, that was zeroed out of the budget by a particular Congressman who didn't happen to like that program.

Now whether that happened or not, I don't know; I wasn't here. It is clear to me that if the Congress recognizes the importance of this dissemination process, and the private sector and the engineering associations get behind it and work with you, as we are prepared to do, to explain how we feel it can be implemented to the best benefit of all, that we will go ahead and take that authority and fund it.

I think that's all the decision that has to be made. If you all in the Congress, with our urging and support, decide to fund that initiative, we're prepared to support and work with you to go ahead and fund it, and we'll have an information system in place if we do, without any new legislation, by the way.

Mr. WALGREN. Thank you very much for that response.

The Chair would recognize Mr. Gregg from New Hampshire, and ask if you wouldn't take the chair in a brief absence by myself and continue on with the recognition of Mr. Bateman at the proper time, and I hope to be right back.

Mr. GREGG. Mr. Weinert, you're saying essentially that we already have on the books all the legislation we need in order to do what these bills are proposing that is appropriate.

Mr. WEINERT. We could meet the objectives of these bills with legislation and institutions that we currently have if we just decide to give them the emphasis and support they need.

Mr. GREGG. The NTIS revolving fund is held up, I think, in Commerce and Energy right now. It's a $5 million fund, as I recall.

You pointed out that NSF is now aggressively pursuing the cross-fertilization programs—or however we want to describe them.

The momentum to accomplish these goals appears to be in the Congress today, and as a result of that, we've got these bills before us. Some of these bills go beyond the proposals which you seem to be endorsing. Do you support direct grants——

Mr. WEINERT. No.

Mr. GREGG [continuing]. For commercialization.

The appropriate role, it would seem to me—and tell me if you agree with this—would be for the Congress, rather than to create new agencies and to pass new legislation, to aggressively pursue the legislation it has on the books.

Mr. WEINERT. Yes; at this time, certainly as the NSF is evolving this new role, we ought to see where it's going to go, how far we can take it.

You know, if 5 years from now we decide we really need to consolidate all these things into a new agency, we ought to reexamine that, but I don't think there's enough evidence on the books now that says we're really going to gain that much for the tremendous cost we're going to pay in dislocation and the overhead of a new agency, to justify bringing it all together in a single organization at this time. I think we need to pursue what we have.

Mr. GREGG. How about a simple sense-of-Congress resolution that says we've passed all these laws, let's now use them?

Mr. WEINERT. That's much more in your realm of interest than mine, but that seems to make sense.

Mr. GREGG. I'd yield to the gentleman from Virginia.

Mr. BATEMAN. Thank you, Mr. Chairman.

I got in late, as I'm sure you're aware, Mr. Weinert, and I enjoyed what I heard. It seems to be fully consistent with the thrust of my thinking before I got here.

Given the fact that I'm doing all this coughing and I agree with what you said, I'm going to withhold any questions.

Mr. **Gregg**. If I could follow up with one further question, do you support the direct grants for generic technology development as opposed to commercialization?

Mr. **Weinert**. You're talking about the mechanism to fund it through one of these generic centers?

Mr. **Gregg**. Right.

Mr. **Weinert**. By a direct grant.

What we support in these generic centers is a cooperative effort that involves industrial private sector money and input as well as Government and education cooperation. It's a tripartite arrangement where the educational community, the Government, and industry work together, and we're not talking about the Government sitting out here setting priorities and giving out money and saying, "All right. Now you all go to work on this with the money that we're giving you," a la the sewage construction grant program, for instance, that's run by EPA, although that is not 100-percent Federal either.

Mr. **Gregg**. Thank you very much. I thank all the witnesses for taking time out of their busy and hectic schedules to help us with this very immediate problem and one which I think the Congress has to address.

We stand adjourned until tomorrow at 9:30 a.m.

Mr. **Weinert**. Thank you, Mr. Chairman.

[Whereupon, at 12:05 p.m., the subcommittee was adjourned, to reconvene at 9:30 a.m., Wednesday, June 13, 1984.]

FEDERAL ORGANIZATION FOR TECHNOLOGICAL INNOVATION

WEDNESDAY, JUNE 13, 1984

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:33 a.m., in room 2325, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Present: Representatives Walgren, MacKay, Lundine, Boehlert, and Skeen.

Mr. WALGREN. Today we continue our hearings on Federal Organization for Technological Innovation by focusing on legislation which has been introduced by various Members, encouraging the development of technology for robotics and manufacturing.

In particular, there are two bills, introduced by Mr. Fuqua, the chairman of the full Science and Technology Committee. They are H.R. 4047, entitled the "Robotics and Automated Manufacturing Systems Research and Education Act"; and H.R. 4415, the "Manufacturing Sciences and Technology Research and Development Act," which is the House counterpart of a Senate bill, S. 1286, that has been introduced by Senator Slade Gorton. Both bills are concerned with establishing programs to conduct research and development for improved manufacturing technologies.

In addition, the subcommittee will also be discussing H.R. 4245, the "National Professions and Technology Foundation Act," which builds on another bill entitled the "National Technology Foundation Act" and includes some threads covering all the professions which address national needs in this area.

This committee has an ongoing interest in innovation and technological change. It is our charter in the Congress to be a public forum for ideas and suggestions that respond to the problems in particularly the scientific area. Certainly our economy needs an ongoing review in this area. Our problems are great, and the pace of change is perhaps too quick for this organization as a government to keep up with. On the other hand, we want to follow these areas as closely as we can to bring knowledgeable comment into a formal process which can then be there for the review of other Members of this body and other governing agencies, both in the executive and in the Congress, so that we have a record that can give us the best guidance in this area.

Congressman Fuqua was going to lead off this morning but he is starting his own hearing down the hall, and therefore, has to be delayed in the agenda, so let's go directly to Dr. Tesar, a director and graduate research professor at the Center for Intelligent Machines and Robotics at the University of Florida.

Dr. Tesar, welcome back to the committee. We appreciate your being here. Just as a matter of form, all the witnesses should know that written statements will be reproduced as submitted on a word-by-word basis, so they will be in the record for later review. We certainly want to encourage you to use the time that we have for whatever emphasis of points and development of points that you feel it would be good to focus on. Therefore, if you would, present the oral testimony in that fashion. We certainly appreciate you being here.

STATEMENT OF DR. DELBERT TESAR, GRADUATE RESEARCH PROFESSOR OF MECHANICAL ENGINEERING, AND DIRECTOR, CENTER FOR INTELLIGENT MACHINES AND ROBOTICS, UNIVERSITY OF FLORIDA

Dr. **Tesar**. Thank you very much, Congressman Walgren. Again, it is a pleasure to be back and to have another opportunity to support the congressional interest and activity in the field of robotics in manufacturing. What I would like to do is simply to mention that my testimony, which is written, covers a finite number of topics:

First of all, that there is an international race that is ongoing in the field of robotics; that robotics has an economic basis for its interest, not only by Congress but also by industry. I summarized in the testimony a fairly extensive statement on the next generation of robot technology, which is appended in much more detail at the end of my written testimony.

I also include in this written testimony, structural questions to enhance U.S. productivity, which looks at some of the principal issues facing industry when it comes to technology base and human capital for manufacturing. Then I make a few specific comments on the bills themselves, specifically H.R. 4047 and H.R. 4415, referencing some updated data that I am now presenting to the committee on what's happening in our international competitiveness in the trade in manufactures, specifically in the area of mechanical technologies.

So with that in mind, Congressman Walgren, I would like to use the overhead projector and try to summarize my principal points by using the slides.

Mr. **Walgren**. Fine.

Dr. **Tesar**. I think you can hear me adequately. Is that right?

Mr. **Walgren** Yes, fine.

Dr. **Tesar**. First of all, economics for U.S. manufacturing is one of the points I am going to be raising, looking at the R & D priorities for the system, very quickly, looking at the U.S. weakness in technology associated with manufacturing, briefly commenting on the international race for robotics, describing very briefly the next generation of robot technology, and then specific comments on the bill itself.

Without being too repetitive, I want to summarize some of the issues which may put this robotics bill into context or perspective. First of all, when it comes to the gross domestic product distribution for the United States, manufacturing remains at about 22 percent of the gross domestic product which overwhelms all of the other wealth generators that we have in our society. Furthermore, I might say that it is very similar to the breakdown that you have in almost every industrialized nation.

In the 1983 trade exports and imports, we find some new issues showing up fairly clearly. Continuing a deficit in the nonmanufactures of about $50 billion for 1983, that loss seems to be accelerating for 1984, from all indications in the public media. On the other hand, 63 percent of our total trade is in the field of manufacturing which no longer is a strong indicator of the strength of the United States. We are now losing at the rate of about $30 to $35 billion explicitly in manufacturing trade for 1983, and it looks like it is going to be much more severe than that in 1984.

Now if you look at the manufacturing field and break it down into four components, exports are at about $55 billion for mechanical and about $100 billion imports, so we have a loss of about $35 billion just in mechanical technology, which includes the making of shoes and clothing, textiles, automobiles and equipment of that type. Chemicals are fairly strong; they represent 12 percent of our trade. Electricals are weakening, we might say, slightly negative in fact at this point at 13 percent of our total trade. Nonetheless, our biggest problem is right in the field of mechanicals, especially in the civil sector.

The history of the trade in the mechanicals can be shown on this chart. This is now the trade balance in the manufactures in billions of dollars, this being $10 billion right here. You see that it begins to weaken in the 1968 through 1972 period of time. It had a tremendous shock of $20 billion because the OPEC countries invested into manufacturing in the United States. In 1975 there is a very sharp turnaround because of the international weakness in the market shares of different countries, and also OPEC countries stopped investing in the United States. In 1978 the dollar was weakened such that we had a turnaround very rapidly. In 1980 when the dollar was strengthened it started to fail very rapidly, so that by 1983 the loss in manufacturing trade balance was $28 billion, explicitly. You see that this shows, that these rather drastic changes reacting to these different external economic pressures indicates that the United States is no longer an isolated society when it comes to wealth generating and manufacturing. We must be more and more conscious of our international competition than we have been in the past.

The mechanicals specifically represent most of our manufacturing capability, and their trade history looks something like this. Already in 1965 the mechanicals technology was weakening rapidly; by 1972, losing at the rate of about $4 to $5 billion; a $14 billion shock during the period of the OPEC investment into U.S. manufacturing; broke extremely rapidly in 1975 down to the point where the dollar was weakened in 1978; a small resurgence in the mechanicals, not very much; and all the way down to a total loss of $34 billion in 1983, a loss of perhaps $50 billion or more for 1984.

So this again suggests that we do have a continuing weakness in the tech base, human capital, investment capability, in manufacturing in the United States, specifically in the mechanicals.

The breakdown in the mechanicals can be seen somewhat in this chart. Here we see that the heavy machinery area is 40 percent of our trade, which is slightly positive as of 1983. There is a strong history in this area, as I will show you on the next chart. The light machinery area, however, has weakened dramatically, losing $18 billion in 1983. Robots are the ultimate light machine; the ultimate light machine meaning quality, precision, response to the market. We see that this technology base is not strong in the United States where, for example, in northern Europe it is strong and depends heavily upon the universities.

Aircraft is about 5 percent of our manufactures and is a strong winner. Our cars and trucks, however, essentially 25 percent of our total trade, was about a $25 billion loser for 1983, so you see the breakdown in the mechanicals indicates that we have two primary deficiencies. One is the light machinery area, which is precision technology like robotics, and one is in the area of aggregate technology associated with automobiles.

If we look at the history of heavy and light, we see this that occurs: The heavy machinery area is oscillating in response to international pressures like all other technologies, but primarily it was in a very strong position during the 1975 through 1981 period of time, but is now beginning to fail rapidly because of intense international competition in the heavy machinery area, specifically the infrastructure technologies like machine tools which are easy to target by other countries.

Light machinery, however, is more aggregate of technology, covers a much broader range of topics, but you see that it has been falling to the level of a $18 billion loss in 1983. It does, however, oscillate from international pressures just like all the other manufacturing fields.

In the aggregate of the 20 worst mechanicals, as an indication of our weakness internationally in trade, you see a cumulative loss in competition for the United States that looks like this. You have essentially zero loss in 1965, losing at the rate of $54 billion for 1983. This can be projected to a loss of about $75 billion for 1984, indicating what we now know about our trade in the manufacturing field. So if you just take 20 of the most negative trade categories in the field of machinery and mechanics, which is the kind of uniform technology associated with robotics, then you see that we have a uniform tech base problem, infrastructure problem for the United States which does not seem to be self-correcting. Unless there are new incentives brought forward, you wouldn't expect correction in that particular field.

How did we get to this position of difficulty in our trade and competition? To some extent you can see that we do provide very high levels of risk capital from the Federal Government. Forty percent of the risk capital for electrical technology in the United States comes directly from the Federal Government. For aircraft, 77 percent of their money comes explicitly from the Federal Government, and these numbers are actually increasing since the period of time when this information was available, in 1976.

On the other hand, machinery, where robotics is properly located, to produce products to compete in the civil sector has only 6 percent of the Nation's R&D and very little money from the Federal Government to provide long-term development, new initiatives, human capital, that sort of thing. So, again, we have almost no doubt in our interpretation of why the United States is having difficulties in the civil sector manufacturing field.

Now we also need to look at how we compare the civil sector trade, which is 60 percent of our manufacturing trade, with our R&D nationally. Here you see we have about 60 percent of our total trade in manufactures supported by 6 percent of the Nation's R&D, so there is about a 10 to 1 imbalance between what we should expect in the manufacturing field and what we actually put into it. On the other hand, you see the chemicals area and the electricals area are very strong in R&D and aircraft is very strong in R&D relative to the trade percentages, so we see there is a major imbalance associated with the civil sector.

On the other hand, we know that to a great extent the Federal Government provides the longest lead time research commitments, advocacy, and human manpower, human capital and what have you, and now we see some really strong imbalances. Some of this has been presented to the committee in the past but I want to put it all together in perspective—60 percent of our trade supported by 0.7 percent of the Federal R&D dollar, which means that you have essentially an 80 to 1 or roughly a 100 to 1 imbalance between the civil sector priorities for manufacturing and the technology base. The longest term commitments to a tech base would be human capital. We are putting at the Federal level, virtually no money in this area at all.

On the other hand, if you look at the electricals at 31 percent and the aircraft at 54 percent of the total R&D dollar for manufacturing, you have a total of 86 percent of the Federal R&D dollar in those two categories. I sit on the Science Advisory Board for the Air Force. In that capacity I have a very high level of awareness of the threat issue, and I wouldn't by any means whatsoever diminish these particular levels of priority. I would, however, suggest that this imbalance is not to our great benefit.

One other issue that needs to be looked at, and it was partially looked at recently by the administration in the tax bill in 1981, but there are still some overall problems for the overall percentage taxation rate for U.S. capital. If you look at the zero inflation rate, 6.7 percent inflation rate, 10 percent inflation rate, in turns of the basis of taxation in the area of manufacturing, commerce, and the service sector, you find out at roughly the 6 or 7 percent inflation rate manufacturing has to pay today about 4 times as much for its capital, to continue its investment in human capital and new plants and equipment, as does the service sector. That really means one of the basic problems we have in manufacturing in this country is the ability to reinvest without long-term risk capital from the Federal Government. So risk capital in nondefense manufacturing, for long lead time development, is just too expensive and we have a hard time staying alive relative to societies that do the reverse or have inverse priorities.

As a method of financing new initiatives, what have you, debt financing has a negative tax base of about minus 23 percent at an inflation rate of 6.7 percent, where for example new issues of stock cost you 87.7 percent and retained earnings cost you 57.3 percent, with a desired 10 percent return on investment. So we say that in general for those kinds of industries that are highly cyclical, like the machine tool industry, those industries that cannot predict certainty in the market, that have a lot of international competition, like the machine tools, third tier contractors, et cetera, debt levels must be as low as possible just to survive because of the cyclic nature of investment. So we have then a problem of risk capital for R&D and long-term development because of this tremendous inversion of priorities and the incentive tax base that we have for the United States in manufacturing.

What is the end product of that? The end product of that is that the Japanese and northern European countries are investing at a much higher rate into plants and equipment, human capital, and new technology than we are. The Japanese are investing at the rate of 27 percent for the period 1972-78, while the United States is investing at the rate of 14.5 percent, so it is very clear that there is not enough reinforcement in our system. The end product of this is that there is almost a perfect correlation between the lack of investment on the United States part—here is your investment rate, up to 30 percent for the Japanese—and your productivity growth for the United States at the lower end of the spectrum of all the competing nations. We see then that Japan is very strong in its investment rate and growth in productivity. This correlation suggests that this is more or less uniformly the case among all Western countries. So if we do have a good correlation between input and output, we know that input is a primary difficulty in our policy in the United States.

If we just look at one specific issue—that is, the light machinery area, an $18 billion loss in 1983, again which is primarily associated with technology robotics—our basic industry is going to other countries. This is one of the most logical and expected results of not being able to invest. The jobs associated with these industries are being exported, pressures on technological institutions like universities and research laboratories are being reduced, and there is loss of tax base to the Federal Government itself.

The ultimate light machine is a robot, which means precision, quality, generic technology, reduced cost of the product, and flexibility—that is, response to the market. We need to work in the field of robotics so we can protect at least this field of light machinery and the products of those machines.

One question that is frequently raised is the question of tariffs: Should we not protect our home market with tariffs? All indications from a study that I made of the Australian environment is that that would be a very foolish idea. This slide here simply highlights my conclusion, which is that if you look at the percent of protection that the Australians have, which is a very uniform activity for the Australians—they are very conscious of tariffs—for example, in the area of clothing they have a total of 130 percent protection. Machinery and appliances has about 40 percent protection. What you have here is a percent of penetration into the home markets relative to the protection in those home markets in Australia, and you see that the curve is almost perfectly smooth—that is, there is almost a perfect inverse correlation between the protection that the Australians have and the penetration into the home markets, which suggests that no other protection exists in the Australian market. That is, from my point of view, technology—the other protection that you might provide to protect your jobs and wealth—is not existent in Australia, and there are a lot of reasonable explanations for that in the Australian case.

To summarize what I have said, I would just like to point out that 6 percent of our total national R&D supports mechanical manufactures, so we have a 10 to 1 imbalance overall. Only 0.7 percent of the total Federal R&D supports 60 percent of our trade, so we have essentially a 100 to 1 imbalance between Federal policy and economic reality. There is a lack of correlation. This lack of correlation between our R&D policy and economic reality indicates that we don't have a national policy. We have national policy in certain areas but not in the civil sector. Other nations have national policy in the civil sector, and they are capturing our home markets.

These bills deal directly with the low manufacturing R&D capital and manpower for the civil sector, and therefore I support them very, very strongly.

There is an international race ongoing in the field of robotics. Whether we like it or not, it is very symbolic, very much like the field of computers 20 years ago. It's very much in infancy. Nonetheless, robotics is a sunrise industry as perceived in Japan. They have tax incentives to invest, and they have at least 50 percent of the world's robots today in Japan. France has a $360 million, 3-year program, development program for robotics, a long-term commitment similar to those in the proposed bill. Russia has a major national plan. I was there and reviewed their program 3 years ago. Major institutes: Moscow has machines, Kiev has welding, Riga has manufacturing robots. East Germany has been committed by Brezhnev himself to develop robotics, and I had indirect confirmation of that a week ago from a very well-placed researcher in the East who told me that East Germans are now extremely vigorous in the field of robotics, and I suspect very, very few people are even aware of that initiative in East Germany. Bulgaria has an ongoing institute for robotics and is one of the superior countries and very committed to its development.

The United States, for example, has major increased interest in DOD for robotics, and we shouldn't ignore the role that DOD is going to provide. On the other hand, I have to say that in the civil sector there is no cohesive program of any magnitude in the robotics field that would be competitive with those of the civil sectors in France and Japan and Northern Europe.

Briefly, I would like to talk about the next generation robot technology. This in itself would take perhaps several days to describe, but I will just give you the end part of it. First of all, the first generation robot was essentially a read only memory machine. This robot essentially existed from 1960 through 1975. The second generation is Continuous Computer Control, generic motion planning for complex assembly and processing. We are about halfway through that generation today. This technology is widely available, is now being marketed across the world.

The third generation is based on a real time dynamic model, closed loop operation relative to unit process it is performing, and will do precision operations under major disturbances. This technology does not exist today. There is no robot existent with this technology. On the other hand, we will never get to the factory of the future without it.

The fourth generation technology that we can point to is very, very similar to the fourth generation computer, which is based on modules of the technology like computer chips. We want to build robots that have component modularity. We want robot software and hardware units that can be assembled rapidly, so that we have rapid diffusion of new technology without disturbing the system. That's what we do with computers today. This reduces costs and reduces the design-to-market cycle time that we now have in robotics technology.

How can we judge where the future is for the next generation of robots? Essentially, we have a list of advanced applications. We have four primary topics: industrial automation, energy systems operations, military operations, human augmentation, and agriculture. In each of these areas of activity we can list about five principal applications that are yet to be met by robot technology.

On the basis of this, you can get a fairly good idea of where the future of robotics technology should go. If you analyze that relative to component technologies that have to be brought forward, you can rank the future component technology research that has to be performed.

First of all, in the near term—not all the technologies being included there—structural geometry ranks No. 1. The man/machine interface is No. 2, and we will find out eventually that man/machine interface will be the most important long-term component technology for robotics. Prime movers, sensors, graphics, communication interfaces, computer architecture—this shows a priority which should now be accepted by the developers and managers of industrial labs. On the other hand, in the long term—which is where university laboratories perhaps should be—we find man/machine interface to be right on top, completely contrary to the pursuance of autonomous machines today. Looking at this analysis in some depth, the number one priority 10 to 15 years from now will be the combination of man and machine, and the argument should be something like this: If you look at the computer, the way you use it today, it is an interactive fashion. The computer is interactive because it augments the human. What we want is robot technology to do the same in the future; we want the robot to make humans more effective, in its decisionmaking capability or its manufacturing capability or handling whatever he has to perform.

Vision will be No. 2. Computer architecture, the most important technology for mechanical engineers, must be built, and we are not being given enough support from industry in this area. Artificial intelligence is No. 4; sensor technology; intelligent control; communication interfaces.

This shows, then, the most important component technologies for the future in the long-term laboratories that should be built up relative and in response to this bill.

Now how do you judge whether you're making progress on the next generation of robots? Well, you need to establish a finite number of criteria, so I have listed a total of 14 criteria and matched them against the applications, so for all groups of applications you will find that the level of machine intelligence will become the No. 1 criterion for success for this technology as we move forward. Multiple task capability—how generic is the technology? How many different tasks can one machine do? Reliability, mobility and portability, precision, and time-efficient operations—of the 14, those are the most important criteria for success of the next generation of robots, so we do have measures for what we mean by this future technology. We do not have to guess at what this technology might be.

Here is one example that I would like to point out to you. This is simply a little robot, about 3 inches long, that is intended to duplicate the dexterity and the motion capability of a human surgeon. What you are trying to do here is couple his intelligence and enhance his motor capacity. The motor capacity of the human surgeon is heavily limited by jitters and imprecision. What we want to do is make the machine intelligence and the robot technology precision augment the surgeon, so that he can do a lot more operations more delicately, perhaps even remotely if necessary, than he could do before. This little robot has a very specialized force sensor, and dual ceramic, frictionless bearings. It is essentially a throwaway robot. All the intelligence is removed back here, between the man and the computer.

One other component that we have developed at the University of Florida conceptually, and we do a lot of these, this is a module. It is what we call a "Florida shoulder." It has 3 degrees of freedom. It's one of the modules that we would like to build up over a long period of time, put it on a shelf and make it available to the designer so he can put them back together with an expert design system, so that eventually you have a very rapid turnover of technology from one decade or one generation to the next.

I would like to make some specific comments on the bills, first of all on the bill H.R. 4047 having to do with robotics. I would have to say that there is an excellent sense of purpose, direction, and magnitude in this bill. This is a remarkable bill because it has a finite set of goals, it has finite funding, it has finite technology base objectives, manpower objectives, and so on. Therefore, I would suggest that the funding and the purpose and magnitude are all more or less properly done.

There is, in addition, no implied sunset in this bill, which is good, I can assure you. There are no implied indexes for inflation, however, which I would prefer—some indexing in the dollar level of funding. Base money must grow with inflation. The implied number of centers, there are suggested about 10 by implication, which means there would be about $3 million per year for base funding for each of these centers, roughly. My feeling is that this seems a little low in today's market. When you consider human capital is going to be expensive if you want excellence in these centers, it is going to be very expensive to put people together. Twenty people would rapidly absorb that kind of funding, if you put support people around them.

Manpower development must be a high priority. I would like to emphasize this point a little bit. It is important that these laboratories be intimately associated with universities. There is no need to establish additional autonomous laboratories for this technology. What there is a need for, however, is to couple universities and industry with these centers, by means of these centers, and human capital must be one of the primary outputs of these centers. If that is true, then universities must be the framework for the existence of the center. It can't be some autonomous appendage that the university once in a while acknowledges its existence, so we want an intimate relationship between this center and the university.

The NBS center is funded roughly in the bill at $10 million per year. I would say that its primary priority should be tech transfer—accessments of robot technology, economics, university subcontracts or at least for the coupling of their priorities with universities, and then also library functions. In other words, where else can industry, small industry in particular, go for knowledge, knowledge base in this field of robotics but to NBS? NBS should be a focus for this kind of service, and I think tech transfer is one of the priorities, the first priorities that could be met.

Specific comments on H.R. 4415, which is the manufacturing sciences bill: The sense of purpose is correct and the sense of direction is correct, but not well defined. It is very difficult to find out exactly what was intended by the bill, from my point of view. However, the sense of magnitude is, I am sorry to say, woefully lacking, considering the magnitude of the problem now faced in manufacturing, considering the breadth of what we mean by manufacturing.

We are losing at the rate of about $100 billion per year in 1984 in manufactures trade. If we just put aside 1 percent of this loss, it would mean we would have to set aside at least $1 billion per year to have an ability to have impact on this problem, so magnitude is an extremely important issue, and to suggest that we can deal with this problem with small magnitude is a mistake. We must have finite goals for a bill of this type, so I think that that's where the magnitude problem I have comes up.

For example, the $60 million a year intended by this bill represents a very small first step. It will not be an effective national policy, and that's the fundamental issue that I would like to raise on this bill.

Now to give you some idea of the magnitude of the problem for manufacturing science, you can tabulate some of the major areas of interest that should be dealt with. Light machinery systems—tremendous impact on society if we don't have a light machinery technology base, human capital. Northern Europe has a very high priority in this area. You have virtually nothing in this country. Heavy machinery is pretty well dealt with in the United States already but we need major continued emphasis in this area.

Manufacturing processes—welding and force forming or what have you—industrial robots, human augmentation—remote robotics systems is not being dealt with anywhere in the United States except at the Department of Defense. Artificial intelligence, electromechanical problems like prime movers and sensors and precision encoders, engineering, economic and human factors—all of these things should be dealt with in some depth, and so the magnitude of this bill is not sufficient to deal with much of this. Maybe one of these sectors could be dealt by this bill.

Using the Air Force as a model, there is no question that the Air Force has a very well established set of laboratories, approximately 13 research laboratories. They are cohesive and they are targeted. They have funding between $30 and $400 million per year each with integrated Air Force R&D policy. This is not just haphazard. It is very well structured, mission-oriented, long-term, and extremely effective, so we can get a very good idea of the sense of magnitude if you look at the laboratories like the Air Force labs as a guide.

So, overall comment, then: First of all, U.S. productivity growth is below other nations. This is one of the realities we now have to face. Punitive U.S. tax laws work against long-term development in the United States, especially in the civil sector. Trade loss in manufacturing in 1984 approaching $100 billion per year. This is real magnitude.

Civil sector manufacturing has little risk capital or human capital with which to compete. aggressively. Essentially, the argument might be that there would be spin-offs from the defense sector, and certainly there is a lot of technology in the defense sector. However, to absorb the technology base that we are providing in the defense sector means that you have to have a viable tech base and human capital base in the civil sector to make that absorption rapid. We don't seem to have enough there across the board.

We know that technology is 40 percent of the problem. Therefore, it's not all the problem but it's certainly a very important game player. We should look at the fact that the take-home pay per worker in the United States has dropped roughly 50 percent relative to other competing nations in the last decade, so we no longer have the strongest, superior productivity in the world.

Last slide, then. Long-term risk capital: 86 percent of Federal R&D for manufacturing goes to two areas, electronics and aircraft, which leaves out to a great extent our civil sector, and it goes to the defense sector so that they remain competitive, and that is properly so. Many manufacturing areas, however, in the United States, like machine tools, need enhanced risk capital now. They just cannot survive much longer without tremendous infusion.

For example, in Florida, you go to a town very close to me in Ocala and you will find a company that has 95 percent of its machines imported for manufacturing from Japan, and we are going to see a lot more of that as time goes on.

The robotics bill is well conceived and will be of real value to industrial policy for the United States. The manufacturing sciences bill, however, in my opinion is too weak in magnitude, primarily, and not well-defined as to mission and cohesive structure for a response to the problems we now face.

So with that as a summary, I will be happy to respond to any questions.

[The prepared statement of Dr. Tesar follows:]

Testimony

To

Subcommittee on Science, Research and Technology

Hearings On
Federal Organization for Technological Innovation
(June 7, 12, 13, and 14, 1984)
Wednesday, June 13, 1984, 9:30 a.m.
Room 2318 Rayburn House Office Building

For Bills

H.R. 4047: Robotics and Automated Manufacturing Systems Research and Education Act of 1983

H.R. 4415: Manufacturing Sciences and Technology Research and Development Act of 1983

By

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I. THE ROBOTICS RACE IS ON

(Adapted from a lead article in Robotics World, January, 1983, pp. 32-33)

Beginning in 1945, the technology of robotics was derived from the urgent needs associated with handling nuclear materials. Since 1970, however, use of the robotic manipulator capable of duplicating complex human motor functions in industrial applications has made significant in-roads in the field of automation. Today, Japan has established itself as the leader with more than 45 percent of the world's robots. The United States, Northern Europe, especially France, and Russia are establishing robot industries in their countries, with varying degrees of government assistance.

The relative importance of robotics to an industrial country can best be illustrated in terms of the economic significance of mechanical automation in civil sector manufacturing. The U.S. robotics effort is the least cohesive in terms of a targeted national research and development plan when considering all indicators. Manufactured goods represent 60 percent of total U.S. trade activity, with mechanicals (automobiles, office machines, cameras, et al.) representing 80 percent of that total. Yet only six percent of the nation's research and development money is spent to support this important portion of U.S. Trade. Furthermore, only 0.7 percent of the U.S. government research and development in manufacturing goes to enhance technology associated with mechanical manufacturing. This has led to a weakening of U.S. trade capacity in manufactures (i.e., value added goods).

The imbalance between the amount of mechanicals sold by the U.S. and the amount of research and development money invested in the manufacturing process is at the core of the U.S. trade weakness in that field. This is most vividly demonstrated by the fact that the 20 worst deficit generators in the mechanical trades category created a $54 billion trade loss in 1983, equivalent to the U.S.'s trade loss in oil.

In 1978, Japan had a $63 billion surplus in manufactures and Germany had a $49 billion surplus, primarily in civil sector goods. These countries have strong national priorities to vigorously pursue vital technologies such as robotics for manufacturing. By contrast, Australia had a $10 billion trade deficit in manufactured goods (an equivalent, comparatively, of $200 billion for the U.S.), with negative trade ratios approaching ten to one in several categories. It is important to realize that 80 percent of the manufacturing in Australia is mechanical in nature. In most industrial countries, it is estimated that mechanicals represent 70 to 80 percent of manufactured goods. It is in the field of quality (precision) mechanical manufacturing capable of rapidly following a market (the customized product) for a competitive price (more or less) that robots can play a major role. Robotics--and the concept of the intelligent machine--is an emerging technology which can be used as a catalyst to strengthen civil sector manufacturing. Therefore, the field is of the highest importance to a nation's economic well-being.

During the past two years, the Russians have established robotics development and applications as a top national priority. Several scientific academies and institutes have established research teams comprised of 20 to 100 members each.

The Paton Electric Welding Institue in Kiev is the largest. The Soviet Union's current five-year plan calls for the construction of 40,000 robots. Progress is occurring in Russia, since robotics manufacturing increased 88 percent in 1982 to a total of 3,600 units. The range of applications is very similar to those in the West. The Soviets have been major buyers of Western robots, including 50 Unimation robots and several French welding robots by Sciaky. The Soviets are known to have theoretical strengths in artificial intelligence (Leningrad), vision (Kiev), and structural kinematics (Moscow). Their primary weakness derives from their lack of proven component technologies, including compact microprocessors, encoders, servo-valves, precision hydraulic and electrical prime movers, and other robotic devices. Overall, the Russian technology is believed to be a decade behind that of the West.

Among the Communist bloc countries, Bulgaria represents a major center for robotics development outside of Russia. A factory for robotics is being established in East Germany and cooperative ventures among the Eastern bloc countries in robot welding cells are being pursued. An extensive effort to standardize robotic systems, software, and components is now being undertaken by principal decision makers in the COMECON countries. This effort includes a world-wide survey of the state-of-the-art which will result in the listing of technical requirements to meet projected needs over the next decade. On this foundation, component and system technologies will be delegated to groups in the various countries for research and development and manufacture. The goal is to create a rapid, but oderly, expansion of robotics technologies in the Eastern bloc. The importance of this effort was highlighted by a trip by the late President Brezhnev to East Germany, in 1981, to organize that country's portion of this cooperative venture.

The French government recently has added robotics as a new element to its national strategy for enhanced technological vitality. Its minister for research and industry has proposed to spend $360 million over the next three years for robotics. This program includes $36 million for equipment at research laboratories; $325 million for research grants to develop advanced robots; and four to five geographically distributed robotics research centers. The minister states that the goal is to boost French productivity by seven percent annually during the next decade. This is twice the increase expected in the United States.

As we look ahead to the next generation of robot systems, we see not the type of human imitations made famous by Hollywood, but machines capable of precise measurements and movements. The human system performs its functions because of unsurpassed hand-eye coordination. Nonetheless, the human system is probably a very poor model on which to base the design of a machine which will perform precise mechanical operations under load. This fact has not been widely recognized and, to a great extent, slows the scientific community's response to this valid need. No human hand is capable of precision measurement or is capable of precision machining operations under load. Therefore, the human model for robotic manipulators is adequate for the simple repetitive tasks now being pursued in industry such as pick-and-place, spot welding, spray painting, surveillance, and unloaded assembly. A precision system capable of high loads in real-time operation could perform precision machining without jigs, precision inspection during operation, multi-level operations under CAD/CAM control, and force fit assembly.

Most manipulator arms are accurate to about 0.0025 inch, which is insufficient for many precision operations such as assembly operations and spatial motion functions such as laser cutting and welding operations. Precision requirements will intensify as robotic systems become smaller and applied to such functions as microsurgery. Generally, deformations under small applied loads in existing commercial systems substantially exceed the state (or repetitive) precision level they can achieve. In addition, the operating environment--temperature, loads, shocks and vibrations--cannot always be considered invariant. Hence, future robotic systems must be much more adaptable to "control-in-the-small," and real-time modeling to meet this second higher level of precision to be developed in the next generation of robots.

Effective development of robotics technology demands integration of disciplines that are frequently considered separate. The primary marriage is of mechanical and electrical engineering, although many other technologies are involved as well. There appears to be insufficient effort toward combining man with machines to enable the uniform penetration of this emerging technology into the workplace. The best opportunity in the immediate future is to balance human and machine capabilities for many applications. As the machine technology improves, less will be asked of the human and more of the machine. This man-machine approach allows the most rapid penetration of the manufacturing market with the near-term technology, allows a gradual and natural transference to more machine-oriented systems, and allows a minimum disruption of the manufacturing workforce.

The time of the intelligent robot is upon us. Virtually every industrialized society has significant research and development in robotics activity as well as a first generation of applications. As the number of applications increase, the demands on the technology will result in carefully integrated systems increasingly made up of modules and scaled more effectively to the task. Miniature robots will be essential for micro-surgery and the assembly and repair of micro-circuits. Not longer will "add-on" technology suffice--the present disciplines of mechanical and electrical engineering will tend to merge into what the Japanese call "mechatronics." Society, in general, will accept the image of manufacturing as a high technology field and reap the benefits of less-expensive, yet higher quality goods.

II. ROBOTICS: AN ECONOMIC ISSUE

(Adapted from Texas A&M Experiment Station brochure, Windows, October, 1982)

Industrial robots are now a reality, and they are having an impact in the field of automation. But what is their potential economic benefit? What are some of their future applications? What are some of the limitations of the existing technology, and is our present R&D effort sufficient and on target? These questions are addressed in this brief listing of issues facing those involved in the development of robots.

Over the past several years, I have analyzed the conditions affecting manufacturing in the United States, documented our relative competitiveness--not only internationally, but especially in our home markets--and pointed to some basic factors associated with our weakening trade capacity.

Manufactured goods represent 60 percent of total U.S. trade activity, and mechanicals (automboiles, office machines, cameras, etc.) represent 80 percent of that total. Yet only 6 percent of the nation's research and development money is spent to support this important portion of U.S. trade. Furthermore, only 0.7 percent of our federal R&D in manufacturing goes to enhance technology associated with mechanical manufacturing. That has led to a weakening of our trade capacity in manufactures (i.e., value added goods).

The imbalance between the amount of mechanicals sold by this country and the amount of R&D money invested in the manufacturing process is at the core of our trade weakness in that field. This is most vividly demonstrated by the fact that the 20 worst deficit generators in the mechanical trades category created a $34 billion trade loss in 1980, equivalent to this country's loss in oil for that year.

Historically, American products were considered to be of good quality. During the 1950's, U.S. machine tools were considered the best in the world. Now, not only is Japanese equipment competitive in quality, but also in price--evidenced by the fact that they now produce 45 percent of the world's robots. Robotics--the concept of the intelligent machine--is an emerging technology which can be used as a catalyst to offset our present lack of competitiveness in civil sector manufacturing. Enhanced manufacturing productivity and reduced hazards to operational personnel performing dangerous tasks are two primary pressures which govern present and future applications for robotics.

It's important to realize that 25,000,000 people are now employed in manufacturing in U.S. industries, of which more than 10,000,000 are performing manual functions on a semi-repetive basis. Today, it is estimated that 9,000 robots are operating in the U.S. This represents a penetration of not more than 1 in 1000. Other countries are outstepping the United States. For instance, increasingly Japanese plant development is moving towards the manless factory or the factory without lights. Similar advanced factory development is taking place in northern Europe.

At the same time, the United States' annual robot research and development budget, some $16.5 million in 1980 is smaller and much less cohesive than that of Japan and France. Advanced factory development similar to that of Japan is taking place in northern Europe. The technology of intelligent, flexible machines as represented by robots is perhaps the central technology involved in these efforts. It's apparent that expanding our activity in the field of Flexible Manufacturing Systems (FMS) will require a major cohesive effort by all parties in the entire U.S. technological community.

Ocean floor activity illustrates the usefullness of robots to perform hazardous tasks. With 19 percent of the world's crude oil coming from offshore sources, the ocean floor has great economic potential if a means of tapping that potential can be found. Costs for offshore drilling efforts are high. The Mobile Oil Condeep drilling platform cost $1.3 billion to handle 42 wells, some as deep as 9,300 feet, and operates in 500 feet of water. Future systems planned by Exxon will be submerged and operated at a depth of 5,000 feet. Remotely Controlled Vehicles (RCV) become economical at these depths. For example, at 1,000 feet, a diver may work for 10 minutes at a total cost of $100,000, while a remotely controlled craft costs $3,500 per day. Today's RCV's are relatively simple, but they can inspect structures, pipelines and cables; place and recover instruments; set explosives; clear fouled lines; and survey under ice.

Examination of robotic technology shows certain important facts. The industrial robot arm may cost up to $100,000. In contrast, the specially designed space shuttle manipulator development and deployment cost was $100 million. It's evident that unusual technology in this field is extraordinarily expensive.

Effective development of this technology demands integration of disciplines that are frequently considered separate. The primary marriage is of mechanical and electrical engineering, although many other technologies are also involved. There appears to be insufficient effort towards combining man with machine to enable the uniform penetration of this emerging technology into the workplace. The best near-term opportunity is to use a balance of human and machine capabilities in many applications. As the machine technology improves, less will be asked of the human, and more of the machine. This man-machine approach allows the most rapid penetration of the manufacturing market with the near-term technology, allows a gradual and natural transference to more machine-oriented systems, and allows a minimum disruption of the manufacturing workforce.

I conclude that: robots are an important part of the future for manufacturing, and that future robots will perform functions beyond today's concepts of the machine; robots will augment human capabilities (not only displace the operator and thus de-skill our workforce); robots cannot be oversold to the young student or researcher, but present robot technology can be oversold to decision-makers in industry; and that our present R&D level in the field is not only insufficient, off-target and incohesive, but that other nations are accelerating their development to our future disadvantage.

APPLICATIONS APPROPRIATE TO AN ADVANCED ROBOTICS TECHNOLOGY

This section of the document is intended to list a representative collection of the most demanding and rewarding unmet applications of robotics. In each case, the application is described in terms of its economic merits, its technical feasibility, and its benefits to the user. Also, in each case, some indication is given as to the necessary technological developments required to satisfy the associated application. One of the more immediate technological gaps is associated with the "open loop" operation for all existing robotic manipulators. Because of this inadequate sensing and real time compensation based on an inclusive dynamic model, it is impossible to maintain spatial coordinate accuracy (with or without external disturbances and loads). Hence many precision operations at small and large scales (micro-surgery, precision light machining, laser welding, etc.) remain unsatisfied. It also means that off-line programming is normally not possible, such that on-line teaching (while no production occurs) is necessary. This means that the data base cannot directly control the robotic system nor support real time inspection. Hence, special precision assembly, clean room operations, micro-assembly and inspection are less likely candidates for robotics. In batch mode manufacturing, this deficiency means the continued high expense and use of numerous machining jigs–a barrier to the factory of the future.

In other applications, the dexterity and obstacle avoidance of existing systems is inadequate. Many of these systems must work in an obstacle strewn unstructured environment. Here, special sensing and an advanced machine intelligence must enhance the information sent to the human operator at the man-machine interface to augment his judgement and decision making capacity. Time, frequently, is of the essence so that exceeding human operating speeds is highly desirable. Strategy and planning to deploy friendly forces and strategy identification of unfriendly forces, sometimes using incomplete data bases or fuzzy data, for military operations has yet to be treated as more than a concept.

INDUSTRIAL AUTOMATION

1. Micro-processing is the spectrum of application of robotics to very small scale industrial operations such as wire soldering of leads to micro-chips, visual inspection and repair of very small assemblies, etc.
2. Complex assemblies involves sequential piece assembly within an obstacle strewn environment where perhaps more than one robot would be necessary (i.e., mounting of a shock absorber on a car).
3. Precision light machining refers to lightly loaded machining tasks in thin stock such as routing, trimming, and deburring while maintaining high tolerance without supporting jigs.
4. Welding in ship structures requires the placement of imprecisely cut thick stock in an egg-crate array and autonomously welding the parts in place.
5. Riveting and deriveting of airframes is the semi-automatic procedure of rivet location, rivet removal, hole inspection and refurbishing, and rivet replacement on airframes with minimum human involvement.

ENERGY SYSTEMS OPERATIONS

6. Nuclear fission reactors could be maintained by robotic systems (especially the PWR steam generator) with minimal occupational radiation exposure and an economic benefit to the nation by 1990 of $1.8 billion/year.
7. Nuclear fusion reactors will require a much higher level and more frequent remote maintenance than fission reactors if their availability is to be 75%.

8. Oil exploration and production on the ocean floor involves maintenance and inspection of the complex ocean floor technologies (valves, pipes, pumps, etc.) in an unstructured environment.
9. Coal production is responsible for 200 deaths/year and considerable cost to the nation due to black lung disease, a dilemma that could be reduced by developing a "manless" coal mine.
10. Nuclear fuel handling and reprocessing has been a long time user of robotics and is now experiencing a new level of technological development at the Oak Ridge National Laboratory.

MILITARY OPERATIONS

11. Remote ocean operations concerns the remote surveillance, personnel retrieval, repair and tactical operations in an unstructured ocean environment.
12. Battlefield operations represents a complex array of operations such as surveillance, autonomous tanks, mine removal etc. to remove personnel from the war zone.
13. Maintenance and emergency repair technology is intended to remove technically trained personnel from the war zone as well as make emergency repairs more cost effectively and reliably.
14. Fuel and ammunition handling will reduce logistics problems, increase reliability, and reduce personnel exposure in the war zone associated with the movement and palletizing of materiel.
15. Planning and strategy operations will augment the field commander's decision capacity as the complexity of field operations increase and provide him with an assessment of the strategy of unfriendly forces.

HUMAN AUGMENTATION AND AGRICULTURE

16. Micro-surgery is intended to augment the precision of the surgeon's motor capacity by a factor of 10 and increase his productive life for operations of the brain, ear, eye, nose and throat including exploratory diagnostics.
17. Prosthetics and orthotics suggests that many partially incapacitated human joints and limbs could be either supported passively or actively to provide improved structural function or they could be replaced by advanced intelligent prosthetics.
18. Agricultural operations associated with non-cereal production are labor intensive and frequently under weather threat. Robotic handling and harvesting equipment could not only reduce costs but also reduce production uncertainties.
19. Accident missions suggest using robotic systems in surveillance, people retrieval, and active threat reduction associated with fires, earthquakes, terrorists, and bomb removal and disabling.
20. Training and service robots are intended to augment humans in education at all levels (truck operation to micro-surgery) with future systems developed for cleaning and maintenance in both public and domestic applications.

MATRIX OF COMPONENT TECHNOLOGIES FOR ROBOTIC SYSTEMS

The integration of numerous technologies is one of the fundamental realities of robotics (or more generally, intelligent machines). Often significant progress in the system development will occur after a breakthrough in a component technology. Hence, except for exceptionally large research facilities, most research efforts will pursue a few component technologies and look to the manufacturer to do the system integration and development. The following 14 component technologies are given to cover the broad spectrum represented by robotics.

1. The structural geometry of the robot, its design and operation for determination of its workspace, reach, dexterity, obstacle avoidance, etc.
2. Structural dynamics of robot systems for modeling of robot dynamic and vibration phenomena for purposes of design and improved operation.
3. Prime movers are the muscles of the manipulator whose precision of operation is dependent on their response and resolution.
4. Actuator modules involves the structural integration of prime movers into modules of 1, 2 or 3 degrees of freedom which can be assembled into robotic systems.
5. End-effectors are the interface hardware and software to perform the handling, inspection, machining, etc. task of the robot; they may include special touch and force sensors.
6. Graphics/CAD of robot phenomena to enhance interactive design and optimization of robotic systems and their integration in complex manufacturing environments.
7. Sensor technology is essential to the existence of an intelligent machine so that it is aware of its own existence and process parameters associated with its operation (manufacturing, maintenance, etc.).
8. Vision is the specialized sensor capable by computer enhancement of rapidly digitizing the physical environment of the robot allowing for comprehensive planning and strategic operation.
9. Artificial intelligence structures the decision making process for multi-layered phenomena in the robot system.
10. Intelligent control involves the layered implementation of various control strategies on global and local objectives.
11. Software modules implies the compact and hardened packaging of frequently used algorithms and their specialized chip assemblies.
12. Computer architecture involves the assemblage of serial and parallel processors capable of treating multi-faceted computational tasks within the concept of real-time operation of the system.
13. Communication interfaces involves the structural distribution of operational decisions and data reduction and transfer of the sensor signals among the various components and layers of the total system.
14. Man-machine interface allows direct human communication with the intelligent robot to facilitate human augmentation in unstructured task applications (micro-surgery, nuclear reactor maintenance, etc.).

Of course, all of these component technologies are of primary importance to the implementation of robotics to this spectrum of applications. Nonetheless, a great deal can be learned by ranking the technologies with respect to their near term and long term relative significance. The long term importance of a component technology should act as a guide to the relative emphasis in basic research among the various technologies. By comparison, the near term value of a component technology should provide an indication of the relative development effort now likely to result in the best short term "pay-off" in actual application. The results of an attempt to quantify these two levels of significance are given in the following partial tabulation.

Normalized Long Term Component Importance		Normalized Near Term Component Value	
Man-Machine Interface	10.0	Structural Geometry	10.0
Vision	9.0	Man-Machine Interface	8.5
Computer Architecture	8.0	Prime Movers	8.0
Artificial Intelligence	7.5	Sensor Technology	7.4
Sensor Technology	7.3	Graphics/CAD	7.1
Intelligent Control	7.3	Communication Interfaces	6.0
Communication Interfaces	7.3	Computer Architecture	5.3

Note that for two application groups, military operations and energy systems, the two component technologies, actuator modules and end effectors, show high long term significance.

The difference between the near term and long term rankings is due to the fact that the technologies are not uniformly available in the near term where it is assumed that they will have the same availability in the long term. In this case structural geometry is thought to be 50% available, prime movers and graphics/CAD at 35%, while vision and artificial intelligence are considered to have reached only 10% of their real potential.

CRITERIA FOR ADVANCED ROBOTICS TECHNOLOGY

The following is a listing of 14 distinct criteria that may be used as indicators of the level of the technology available in an advanced robotic system and may be a useful means to judge progress of the technology under development.

1. Multi-task capability means the number of different physical tasks that can be performed by the same robotic system.
2. Level of machine intelligence implies the level of integration of computer hardware, software, and artificial intelligence to make the system as autonomous as possible.
3. Time efficient operation implies the speed at which the robotic system performs its task relative to the human performing the task alone.
4. Unstructured task level suggests the level of numerical uncertainty of the operation that is to be performed by the robotic system.
5. Geometrical dexterity is an indicator of the motion range the end-effector can move through while performing physical tasks.
6. Portability and mobility implies the level of movement the total robotic system has relative to a stationary (fixed shoulder) manipulator.
7. Precision is an indication of the absolute precision of placement of the end-effector in world coordinates in response to simple numerical commands.
8. Load capacity clearly implies the ability of a robot to carry or resist a given load without major deformation.
9. Reliability is an indicator of the failure rate of the total robotic system.
10. Obstacle avoidance suggests the ability of the robot to avoid obstacles in its work environment.
11. Force sensing suggests the measurement of forces in the manipulator system to be evaluated by the machine intelligence to judge working forces or to compensate for manipulator deflections.
12. Smoothness of operation implies the lack of backlash or very large deformations in the manipulator system.
13. Operational envelope gives an indication of the working range provided by the robot without moving its shoulder.
14. Vision corresponds to shape recognition either by enhanced analog feedback to the human operator or by digitizing the scene and providing numerical shape recognition.

For all applications combined, the most important robotic characteristic does not outrank the least by more than a factor of two. The range is up to a factor of 4 among some of the application groups. This data is partially tabulated below in order to establish the most significant properties of robotic systems for each application group. Generally, as the application warrants or allows autonomous operation, the characteristics of machine intelligence, precision, vision, sensing, and reliability become important. For unstructured task applications requiring a balance between man and machine, characteristics such as multiple task capability, mobility and portability, obstacle avoidance, reliability and unstructured task level have an increased importance.

	Component	Rank
All Groups Applications	Level of machine intelligence	10.0
	Multiple task capability	9.0
	Reliability	9.0
	Mobility and portability	8.6
	Precision	7.8
	Time efficient operation	7.6
Industrial Automation	Precision	10.0
	Level of machine intelligence	9.3
	Vision	8.3
	Force sensing	7.5
	Smoothness of operation	7.3
	Obstacle avoidance	7.3
Energy Systems	Multiple task capability	10.0
	Portability and mobility	8.5
	Reliability	8.0
	Level of machine intelligence	7.2
	Load capacity	7.0
	Geometric dexterity	7.0
	Unstructured task level	7.0
	Time efficient operation	6.5
	Precision	6.5
Military Operations	Level of machine intelligence	10.0
	Portability and mobility	8.9
	Reliability	8.7
	Time efficient operation	7.9
	Multiple task capability	7.9
	Obstacle avoidance	7.7
	Unstructured task level	7.7
Human Augmentation and Agriculture	Portability and mobility	10.0
	Reliability	8.9
	Multiple task capability	8.4
	Unstructured task level	8.0
	Vision	7.0
	Obstacle avoidance	7.0
	Level of machine intelligence	7.0

FOUR GENERATIONS OF ROBOTS[x]

Generations	Period	Technology	Function	Objective
1[+]	1960-80	Read Only Memory (ROM)	Playback of Point-to-Point Motions	Simple Repetitive Parts Transfer
2[*]	1975-90	Continuous Computer Control	Generic Responsive Motion Planning	Complex Light Assembly and Processing
3[**]	1985-2000	Real Time Dynamic Model	Closed Loop Operation Relative to Unit Process	Precision Operations Under Major Disturbances
4[***]	1990-	Component Modularity	Rapid Diffusion of New Technology Without Disturbing Preceding System Structure	Reduced Costs and Design-to-Market Cycle Time

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x--Presented to put the various technologies under discussion into perspective as a tabulation of four generations of robots.

+--Seiko Robot

*--Present Generation

**--Does not now exist in any form

***--Would dramatically broaden robot market.

IV. Structural Questions To Enhance U.S. Productivity in Manufacturing

The following structural questions associated with the condition of U.S. Manufacturing are raised to clarify the role of the legislative initiatives contained in bills H.R. 4047 and H.R. 4415.

1. Competitive Civil Sector Manufacturing

a. Background:

The economic reality is that wealth generation is 1/3 of the GNP of the U.S.A. of which 2/3 is due to manufacturing. Of this 2/3, 60 percent or more is mechanical in nature, primarily in the civil sector. Yet, industry invests less than 6 percent of its R&D and its manpower to meet this need. The federal government invests less than 0.7 percent.

These major imbalances continue to weaken our civil sector and allow penetration into our home markets by other strong civil sectors, i.e., Japan, Germany, and in the future France. These three countries are building their civil sectors by various policies as a top national priority.

b. Comment:

The present bills are directed to solve this apparent imbalance of industrial policy. It is recommended that a careful comparative analysis he made in the NBS center of the relationship between correlated R&D inputs and manufacturing outputs among the major competing nations.

2. Role of Defense R&D in Manufacturing

a. Background:

The U.S. emphasis on defense materiel consumes a larger portion of our limited science and engineering manpower. For example, 86 percent of the U.S. federal R&D for manufacturing (about 50 percent of the total federal R&D) goes to two fields, electronics and aircraft (missiles). Even though one may argue for or against this emphasis, it exists as a reality in our economic system.

Frequently, it is argued that spin-off of the defense R&D will occur to the civil sector. It may be asserted that spin-off is only possible if a vital and agressive technical manpower base exists in the civil sector. Since only 6 percent exists in our civil sector, then other societies which have strong civil sector manpower pools may be primary beneficiaries of this spin-off.

b. Comment:

The role of Defense R&D is a major push mechanism to develop technology in the United States but it may well weaken an otherwise strong civil sector manufacturing effort in the U.S.A. Do other countries have inverse priorities and can a comparative analysis clarify the role of Defense R&D in the U.S.? The proposed bills can create a program to deal with these issues and document the conclusions for policy makers.

3. Relative Role of Investment in Physical Plant and Technological Manpower

a. Background:

The 1981 tax bill made the growth of physcial plant capital more likely--a procedure proven to be effective in the '50s. The administration has not simultaneously taken steps to enhance our human capital appropriate for knowledge based industries. This reduces the resources available to the universities from all sources including industry and the federal government. Hence, as industrial needs shift more and more to technological manpower, the federal government must also shift its policy in proportion to this reality.

b. Comment:

The present bills should ensure that existing manpower in manufacturing be enhanced and that a new generation of young scientists and engineers be trained by a high level of educational activity in the proposed centers associated with universities.

4. Role of the States in Manpower Development

a. Background:

One vital part of the solution is to bring industry and academia together on a negotiated set of objectives for mutual benefit. Apparently, the U.S. government is unwilling--hence, the competition among states may prove a new vehicle (if exploited) to perform a major portion of the human capital enhancement. I.e., leave the physical plant enhancement to the states.

One caveat requires, however, that the universities continue to identify themselves primarily with manpower generation. Too great a movement towards autonomous laboratory functions unnecessarily competes with other mission sectors supported by the community such as government labs, consulting firms, industrial labs, etc.

b. Comment:

The program could provide incentives to education systems at the state level to make possible a natural competition in enhanced manpower generation for manufacturing.

5. Enhanced Role of Industry in Manpower Generation

   a. Background:

   It may seem to be appropriate to ask industry to play a larger role in developing manpower. However, during the past two decades, industry has provided no more than 3 percent of the funds for university research and manpower generation. This is not expected to change significantly since no new incentives have been established.

   Note that by contrast to our 5 percent engineering graduates relative to all graduates in the U.S., Japan has 20 percent, Central Europe has 20 percent, and the Eastern Block has 40 percent.

   b. Comment:

   These bills would strengthen NSF in the field of manufacturing technologies and possibly ensure that DOD augment its role in the universities to generate an increased number of young scientists and engineers by requiring mutual benefit industrial sub-contracts to universities.

6. Control of Inputs Versus Control of Outputs

   a. Background:

   The issue fundamentally comes down to national policy. Should the nation control its inputs or its outputs? Japan controls their inputs first (R&D, manpower, etc.) while Australia controls its outputs (tariffs, minerals, etc.). If a nation attempts to control its outputs, it deemphasizes its greatest asset, human capital for value added. If inputs are managed, the capital resources of the nation are increased but the associated planning must be much more long term and commitments must be maintained over the long term. The contention is that we are increasingly less committed and don't always recognize the inputs that need to be adjusted.

   b. Comment:

   The NBS center should undertake a careful review of the long range effects associated with inputs into our manufacturing system.

7. Lesson from Australia

   a. Background:

   Australia represents a developed country having a scale 1/20th that of the U.S. It has attempted to control its destiny by controlling its outputs (mineral resources in the world market and tariffs to protect its home markets). This approach is beginning to fail. Fifteen years ago, Japan agreed to purchase minerals and coal from Australia if they were allowed to enter Australia's home markets with manufactured goods. Now Japan has the portion of the Australian home markets they need and are shifting their purchases of minerals to other countries such as Argentina and Venezuela. This is a direct form of external manipulation due to weakened Australian manufacturing technology caused by over-protection from high tariffs. It may be too late for Australia, but the U.S. can learn a great deal from this experience.

b. Comment:

The NBS center should undertake an in-depth analysis of the Australian example of a unique structural system for manufacturing to derive lessons for U.S. policy makers.

8. National Policy for Manufacturing

a. Background:

During the last decade the U.S. has lost 30-50 percent of its take home pay per worker relative to other developed societies such as Japan and Northern Europe. In fact, some suggest that the take home pay of northern Europe is 20 percent above that of the U.S. (a numerical issue that should be very carefully verified). If our relative take home pay has deteriorated so badly, why? Since our markets are open to all competition (some of it unfair) our only protection is to run faster than our competition. To do so means that we must have a national policy.

b. Comment:

These bills will prove instrumental in focusing U.S. national policy on technology and away from tariffs.

9. Relative Role of High Tech and Low Tech

a. Background:

Many say that high technology is the answer. It is if properly interpreted. If the product is of quality, if it rapidly follows a changing market, and if it meets a competitive price; then it is high technology. This can be shoes made with robots or it can be microchips made in a clean room, etc. This view eliminates the argument that we should let dying industries die. Such statements mean that we accept technological defeat which then leads to fewer jobs and less take home pay.

b. Comment:

These bills should be structured to avoid the "trap" of giving up on "low tech" industries which can be so destructive for the U.S. economy.

V. 1983 Trade Data in Manufactures Specifically Related to Bills H.R. 4047 and H.R. 4415

Over the past two decades, the U.S. has experienced a significant impact on its ability to maintain a strong competitive position in its trade in manufactures (see Fig. 1). The curve of manufactures trade balance shows a weakening condition already in 1965-1972. In 1972-73, the oil embargo made possible the purchase of many of our manufactured goods by excess petro dollars in the OPGC countries. This broke rapidly in 1975 because of a world-wide recession and became marginal in 1978. At that time, the dollar was weakened and the U.S. trade rapidly improved. However, in 1980, the dollar was again strengthened with the result that our ability to export was dramatically weakened to result in a trade loss in manufactures of $28 billion in 1983.

These large fluctuations show that the U.S. system is heavily influenced by activity in the international market place and that U.S. industry must compete in a world-wide market.

Figure 2 shows that manufactures represents 60 percent of our total trade, that there is a $28 billion deficit in manufactures most of which shows up as a trade deficit of $33 billion in the mechanicals (which represents 80 percent of our manufactures trade). Hence, the bills under consideration must target the "mechanicals" as a first priority in order to best respond to our trade weakness.

The history of trade in the mechanicals is shown in Figure 3. This curve shows weakness already in 1965 moving downward until the OPEC petro dollar shock in 1972-73. The mechanicals broke very rapidly in 1975 and except for a small recovery in 1978-80 due to the weakened dollar, has rapidly deteriorated to a trade loss of $33 billion in 1983. It may be concluded that the curve shows a continuing structural weakness in the mechanicals and that major new incentives by the U.S. government for enhanced activity at all technical levels is now necessary. These bills deal with the essence of this problem but their magnitude is far below that which would have a sufficient influence on our manufacturing system.

The breakdown of the mechanicals into 4 categories shows that two categories are particularly weak (see Fig. 4). The first is in the field of light machinery. Note that the ultimate light machine is a robot (see Section VII of this testimony). The loss in light machinery is now $18 billion and it continues to worsen (see Fig. 5). The heavy machinery field, although still positive, is now under severe pressure--especially in the field of machine tools. Our loss in vehicles is a national disgrace at $25 billion for 1983. In 1984, we are experiencing a trade loss approaching $145 billion showing that our situation appears to be worsening at an accelerating rate. Hence, it becomes urgent to consider these bills now! Not 5 years from now when perhaps irreversible damage to our industry and workforce will have been done. Figure 6 gives an overall view of this accelerating weakness. It shows the loss of $54 billion for 1983 (projected at $70 billion for 1984) in the 20 worst trade categories in the mechanicals. It may be concluded that the bills should address these 20 trade categories as a first priority. To do otherwise is to allow an extremely punishing condition to continue as a significant threat to the economic well-being of the United States.

TRADE TRENDS FOR ALL MANUFACTURES
(FROM 1965 TO 1983)

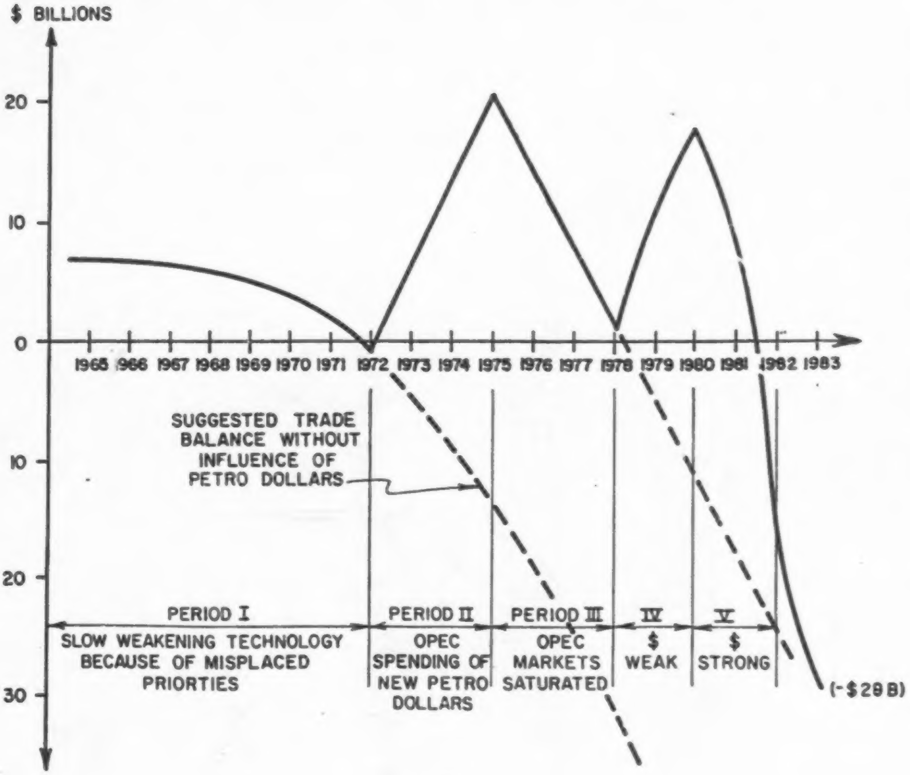


Figure 1

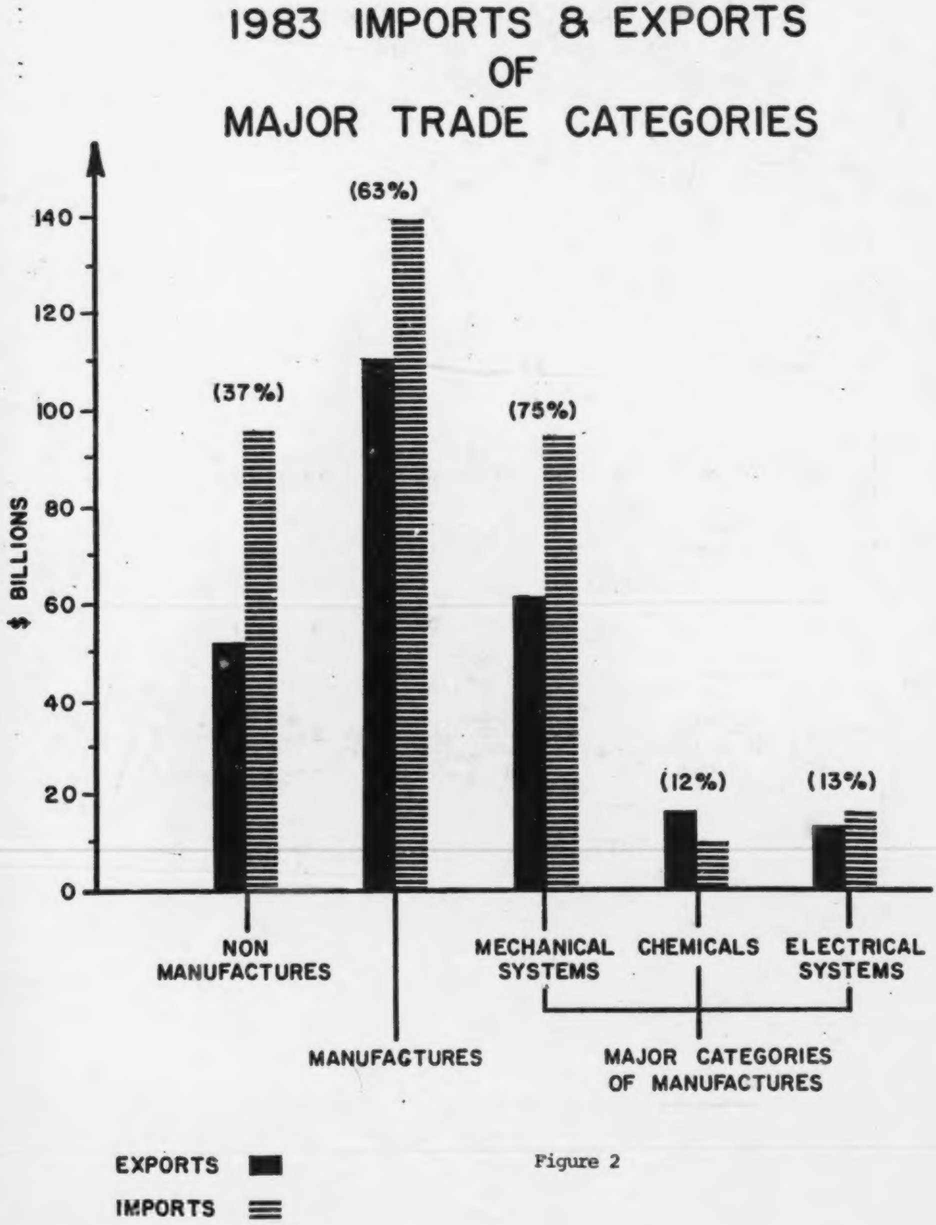
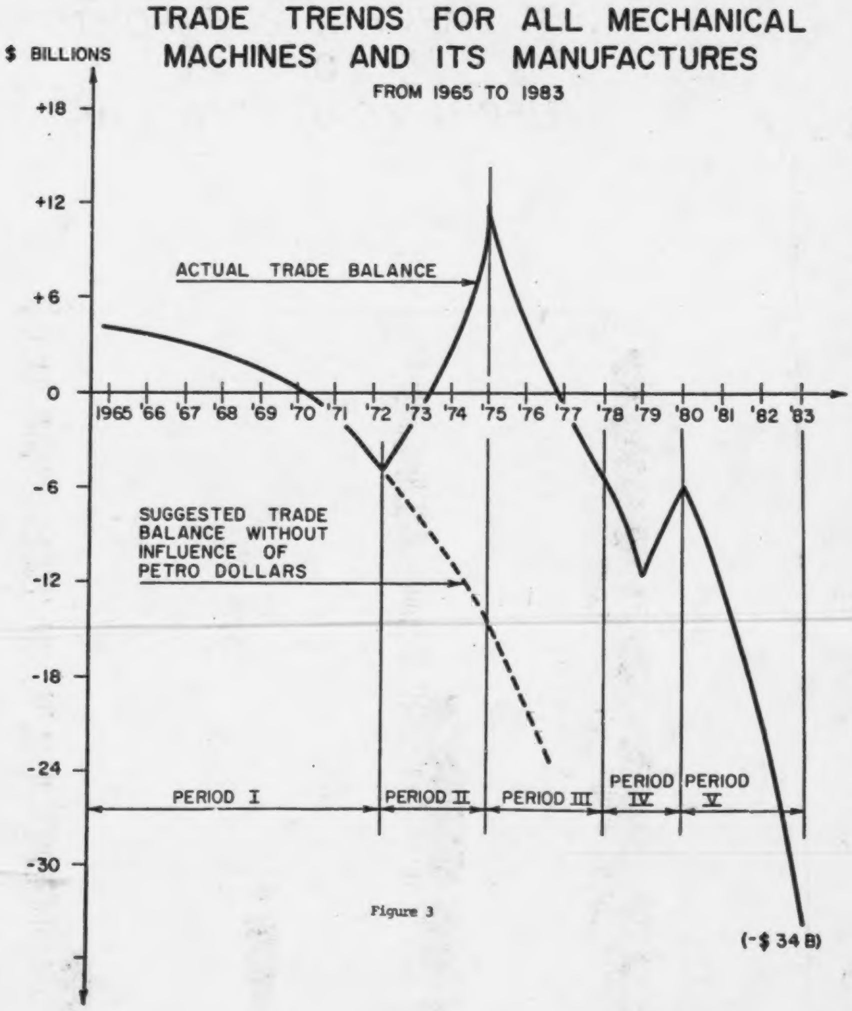

1983 IMPORTS & EXPORTS OF MAJOR TRADE CATEGORIES
$ BILLIONS
140
120
100
80
60
40
20
0
(37%)
(63%)
(75%)
(12%)
(13%)
NON MANUFACTURES
MANUFACTURES
MECHANICAL SYSTEMS
CHEMICALS
ELECTRICAL SYSTEMS
MAJOR CATEGORIES OF MANUFACTURES
EXPORTS
IMPORTS

Figure 2



TRADE TRENDS FOR ALL MECHANICAL MACHINES AND ITS MANUFACTURES

FROM 1965 TO 1983

Figure 3

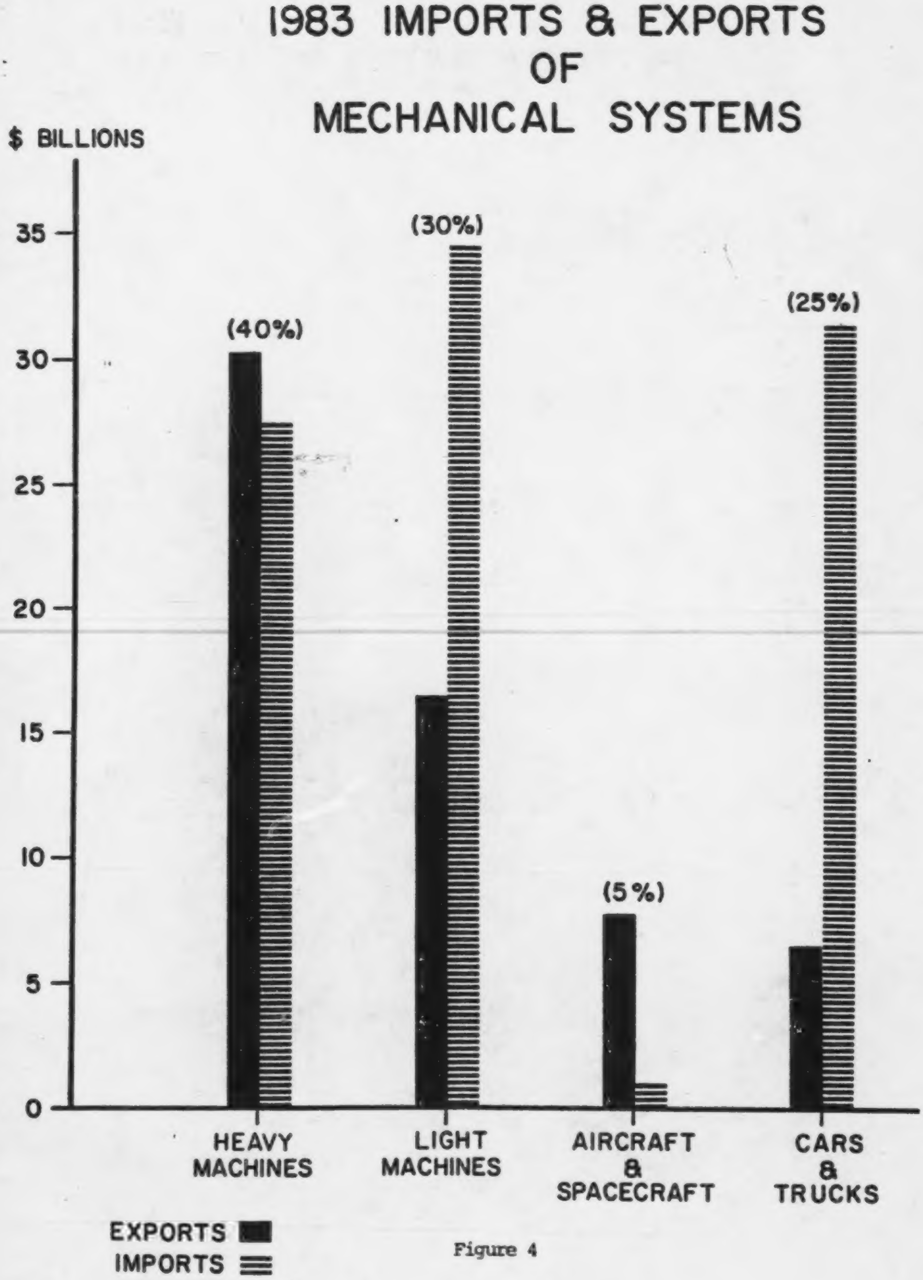

1983 IMPORTS & EXPORTS
OF
MECHANICAL SYSTEMS
$ BILLIONS
35
30
25
20
15
10
5
0
(40%)
(30%)
(5%)
(25%)
HEAVY MACHINES
LIGHT MACHINES
AIRCRAFT & SPACECRAFT
CARS & TRUCKS
EXPORTS ■
IMPORTS ☰

Figure 4

TRADE TRENDS FOR LIGHT AND HEAVY MACHINERY AND ITS MANUFACTURES

FROM 1965 TO 1983

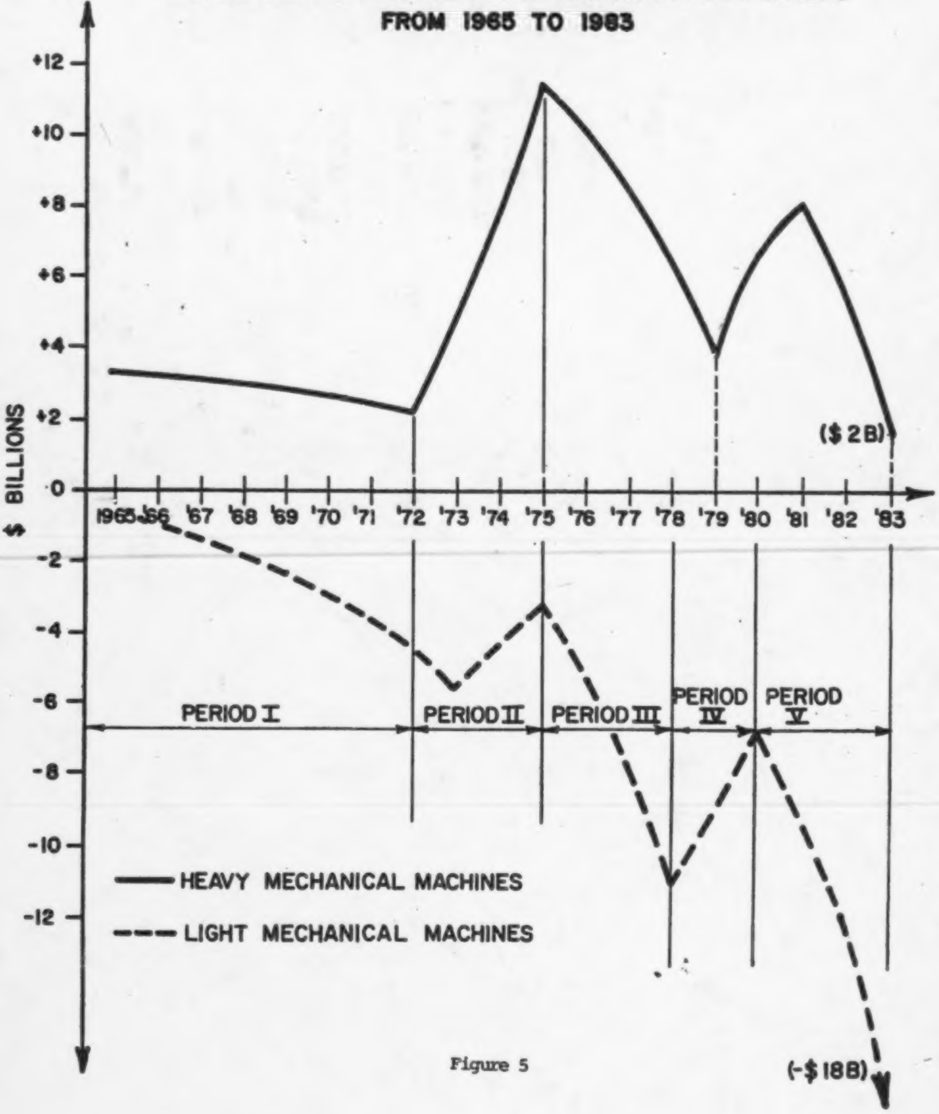


Figure 5

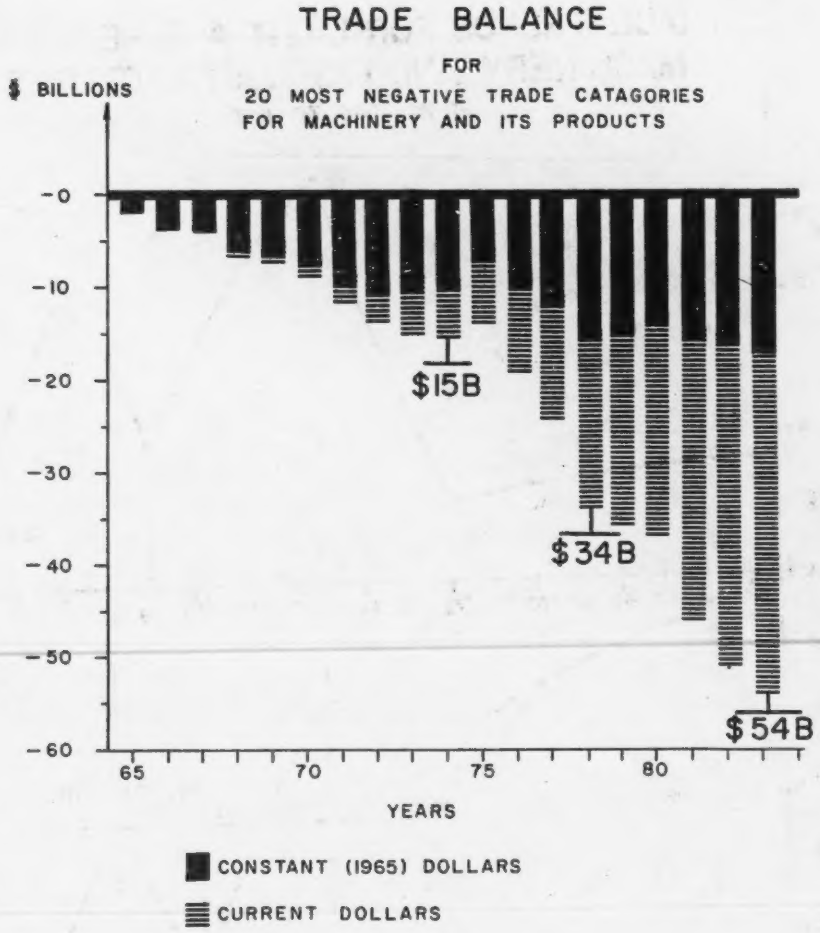

TRADE BALANCE
FOR
20 MOST NEGATIVE TRADE CATAGORIES
FOR MACHINERY AND ITS PRODUCTS
$ BILLIONS
-0
-10
-20
-30
-40
-50
-60
$15B
$34B
$54B
65
70
75
80
YEARS
CONSTANT (1965) DOLLARS
CURRENT DOLLARS

Figure 6

VI. Specific Comments on Bills H.R. 4047 and H.R. 4415

A. H.R. 4047: Robotics and Automated Manufacturing Systems Research and Education Act of 1983.

Overall Comment:

The objectives of this bill show an excellent sense of purpose to respond to a national need especially to meet existing foreign initiatives. The sense of direction to move robotics, as a catalyst to a broad base of technology in flexible manufacturing, forward is properly targeted with sufficient emphasis on basic research and technical manpower to make the program viable. Finally, the level of magnitude is certainly not too high to create an effective national plan.

One might argue for inflationary indeping, etc. in the out years but that can always be dealt with. I am pleased that the bill does not necessarily imply a sunset philosophy for this program since I believe that development in the field will require more than one decade. The important issue is to develop a technology primarily for the civil sector which will grow in parallel with an increasingly active defense sector.

Suggestions:

Sec. 2, Art. 1

(Add) . . .with other major industrial nations which is partially due to aggressive national programs for manufacturing in such fields as robotics.

Sec. 4, Art. 1

(Add) . . .multifunction highly adjustable mechanical structure (such as a manipulator) designed. . .

Sec. 4, Art. 3

(Change) -- "flexible manufacturing system" means. . .

Sec. 5a, Art. 1

Here the question of how many centers may need to be dealt with. If, for example, a total of $30 million/yr. is available to ten centers at $3,000,000 each, this may prove too low to establish centers which can be effective. This is a real dilemma which should be considered on the long term. Also, these centers should have the development of manpower as a high priority. In this case, a large percentage of the researchers should be academic faculty who supervise research students on a daily basis and have a high regard for academic procedures and standards.

Sec. 5a, Art 3

(Change second sentence). Emphasis will be placed on systems intergration, reliability, and performance as well as assessment or the required technology and the benefit to accrue from implementation in new and demanding applications for robotics (nuclear reactor maintenance, precision ligh machining, microprocessing of electrical circuits, etc.)

25

I

98TH CONGRESS
1ST SESSION

H. R. 4047

To advance the national prosperity and welfare, to foster the development and use of robots and automated manufacturing systems, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

SEPTEMBER 30, 1983

Mr. FUQUA (for himself, Mr. BROWN of California, Mr. GORE, Mr. MACKAY, and Mr. BOEHLERT) introduced the following bill; which was referred to the Committee on Science and Technology

---

A BILL

To advance the national prosperity and welfare, to foster the development and use of robots and automated manufacturing systems, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SHORT TITLE

SECTION 1. This Act may be cited as the "Robotics and Automated Manufacturing Systems Research and Education Act of 1983".

FINDINGS

SEC. 2. The Congress finds and declares that—

(1) the productivity and rate of innovation of many United States manufacturing industries are lagging in comparison with other major industrial nations;

(2) there is a shortage of skilled manpower and trained technical and scientific personnel in manufacturing;

(3) the widespread implementation of robotics and automated manufacturing technology can improve productivity, enhance quality, and increase competitiveness in a wide variety of manufacturing occupations;

(4) because robotics and automated manufacturing systems affect widely divergent segments of industry, a program fostering these technologies should be of broad benefit to manufacturing firms;

(5) a national program of research and education in robotics and automated manufacturing systems is essential to insure the timely and widespread implementation of these technologies; and

(6) to insure the success of this program, the active participation and support of industry, universities, labor, and government are required.

PURPOSE

SEC. 3. It is the purpose of this Act—

(1) to promote research relevant to robotics and automated manufacturing systems and provide for in-

dustry, university, labor, and government cooperation in that research;

(2) to promote the education of scientists, engineers, and technicians needed for the theoretical understanding, design, construction, installation, use, and maintenance of robots and automated manufacturing systems; and

(3) to promote technology transfer between research laboratories and United States industry related to robotics and automated manufacturing systems.

DEFINITIONS

SEC. 4. As used in this Act—

(1) the term "robot" means a programable, multifunction manipulator designed to move material, parts, tools, or specialized devices through variable programed motions for the performance of a variety of tasks;

(2) the term "robotics" means the study of robots or the practice of using robots; and

(3) the term "automated manufacturing system" means two or more operating stations of robots or fixed sequence automatic machines interconnected by a transport system, where both operating stations and transport system are controlled by a computer which

performs such functions as production planning, task scheduling, and control of part and tool movement.

RESEARCH AND TECHNOLOGY TRANSFER

SEC. 5. (a) CENTERS FOR INDUSTRIAL TECHNOLOGY.—(1) There shall be established Centers for Industrial Technology (as described in sections 6, 7, and 8 of the Stevenson-Wydler Technology Innovation Act of 1980 (15 U.S.C. 3705-3707)) devoted to robotics and automated manufacturing.

(2) Each such center shall investigate a discrete segment of robotics and automated manufacturing systems. Areas of emphasis should include manufacturing process, control system, sensors, sensory data analysis, software development, kinematics and dynamics, machinery design, teleoperation, artificial intelligence, human augmentation and prosthesis, and human and economic factors associated with the introduction of robots and automated manufacturing systems into society. Human and economic factors research topics, as they pertain to robotics and automated manufacturing shall include training and retraining of employees; dislocation assistance; health and safety; regulation; incentives for use of robots and automated manufacturing systems; economic factors; trade; and income distribution.

(3) At least one such center shall conduct research on products and processes that can be commercially developed

within five years after feasibility demonstration in a research center. Particular emphasis shall be placed on systems integration, reliability, and performance.

(4) Such centers shall promote domestic technology transfer from the centers to private industry and the public sector by publishing reports, holding meetings and conferences, establishing positions for visiting research scientists, consulting, and providing data bases for information exchange.

(5) Each such center shall coordinate its research activities with other centers to minimize duplication and shall share nonproprietary information through meetings, exchange of scientists, and networking of computer systems.

(6) The directors of such research centers shall meet at least annually to exchange specific plans and programs for the upcoming year to coordinate research activities.

(b) FEDERAL RESEARCH CENTER.—(1) There shall be a Federal Research Center on Robotics and Automated Manufacturing at the National Bureau of Standards. The Center shall focus its research and development on (A) measurements and standards required in robotics and automated manufacturing systems, including interface standards for integrated robot systems and (B) systems integration, reliability, and performance.

(2) The Center shall coordinate its research activities with the centers described in subsection (a) and shall share information through meetings, exchange of scientists and network computer systems.

(3) The Director of the Center shall meet at least annually with the directors of the research centers described in subsection (a) to exchange specific plans and programs for the upcoming year to coordinate activities.

(c) RESEARCH PROJECTS.—The National Science Foundation shall provide project grants for basic and applied research relevant to robotics and automated manufacturing. Areas of emphasis should be the same as those described in subsection (a)(2).

(d) LIMITED RESEARCH AND DEVELOPMENT PARTNERSHIPS.—The Department of Commerce shall promote the formation of limited research and development partnerships which undertake research and development in the areas described in subsection (a)(2).

EDUCATION AND TRAINING

SEC. 6. The National Science Foundation is authorized to support the education and training of scientists, engineers, and technicians needed for the theoretical understanding, design, construction, installation, use, and maintenance of robots and automated manufacturing systems. Such support may include, but need not be limited to, providing funds for:

Graduate fellowships and traineeships, undergraduate scholarships, instructional equipment, the development of curricula for intramural or extramural use at undergraduate and graduate levels, and postdoctoral fellowships. Such support shall be provided on a matching basis with other sources of support, whenever possible.

PROGRAM REVIEW

SEC. 7. (a) PROGRAM REVIEW BOARD.—The National Research Council shall establish a National Robotics and Automated Manufacturing Systems Program Review Board. The Board shall include persons representative of business, academia, labor, and government and shall be reasonably balanced in terms of representatives from such areas. Each member of the Board shall be knowledgeable about robotics and automated manufacturing as they pertain to the group represented by the member. Members shall be appointed to the Board by the National Research Council and shall serve rotating, staggered terms.

(b) BOARD FUNCTIONS.—The Board shall review all aspects of Federal involvement with robotics and automated manufacturing systems, report its findings, and make recommendations regarding such Federal involvement. Aspects of Federal involvement considered by the Board shall include: (1) Activities under this Act, (2) tax law applicable to robots and automated manufacturing equipment, (3) the National

Robot and Automated Manufacturing Systems Leasing Corporation, and (4) activities of the Department of Defense or any other Federal agency in robotics or automated manufacturing systems. Reports may be issued at any time by the Board and may be addressed to any audience. At least once every two years, however, the Board shall prepare a report evaluating all aspects of Federal involvement with particular attention to whether the purposes of this Act specified in section 3 are being achieved, and shall transmit that report to Congress.

(c) BOARD OPERATIONS.—The Board shall select its own Chairman, subject to approval by the National Research Council. The Board may establish subcommittees and advisory panels. The Board shall meet no less than three times annually. The Board shall conform to the operating procedures of the National Research Council, except as otherwise provided by this Act.

(d) BOARD FUNDING.—Funding for operation of the Board shall be provided by the National Science Foundation.

AUTHORIZATION OF APPROPRIATIONS

SEC. 8. (a) RESEARCH.—There is authorized to be appropriated to the National Science Foundation for the purposes of section 5 (a) and (c), $20,000,000 for the fiscal year ending September 30, 1984, $40,000,000 for the fiscal year ending September 30, 1985, and $50,000,000 for each of the fiscal years ending September 30, 1986, 1987, 1988, 1989, and 1990.

(b) FEDERAL RESEARCH CENTER.—There is authorized to be appropriated to the Secretary of Commerce for the purposes of section 5(b), $10,000,000 for each fiscal year ending September 30, 1984, 1985, 1986, 1987, 1988, 1989, and 1990.

(c) LIMITED RESEARCH AND DEVELOPMENT PARTNERSHIPS.—There is authorized to be appropriated to the Secretary of Commerce for purposes of section 5(d), $2,000,000 for each fiscal year ending September 30, 1984, 1985, 1986, 1987, 1988, 1989, and 1990.

(d) EDUCATION AND TRAINING.—There is authorized to be appropriated to the National Science Foundation for the purposes of section 6, $5,000,000 for the fiscal year ending September 30, 1984, $7,000,000 for the fiscal year ending September 30, 1985, and $10,000,000 for each of the fiscal years ending September 30, 1986, 1987, 1988, 1989, and 1990.

(e) PROGRAM REVIEW.—There is authorized to be appropriated to the National Science Foundation for the purposes of section 7, $250,000 for each of the fiscal years ending September 30, 1984, 1985, 1986, 1987, 1988, 1989, and 1990.

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98TH CONGRESS
1ST SESSION

H.R. 4415

To establish a program to conduct research and development for improved manufacturing technologies, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

NOVEMBER 16, 1983

Mr. FUQUA introduced the following bill; which was referred to the Committee on Science and Technology

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A BILL

To establish a program to conduct research and development for improved manufacturing technologies, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Manufacturing Sciences and Technology Research and Development Act of 1983".

FINDINGS

SEC. 2. The Congress finds that—

(1) various sectors of private industry, the Federal Government, and the United States research establishment have not devoted sufficient attention to research

on developing new processes and methods to improve the Nation's capability to manufacture goods;

(2) while manufacturing industries are essential to the economic well-being of the Nation, many manufacturing processes and methods are no longer capable of producing goods as reliable and cost-competitive as those produced by foreign industries which utilize modern manufacturing methods and processes;

(3) domestic manufacturing is increasingly threatened by external competition and the development by foreign countries of more efficient manufacturing processes and technologies;

(4) outdated manufacturing methods and processes result in higher costs and goods and services of inferior quality, which place great burdens on consumers of such goods and services;

(5) outdated and inefficient manufacturing processes hinder domestic commerce;

(6) transportation and delivery of manufactured goods are vital components of the Nation's interstate commerce, and a decline in consumption of domestic manufactured goods due to inefficient manufacturing processes produces a resultant decline in transportation;

(7) manufacturing contributes large amounts of revenue to the Nation's gross domestic product and employs more than one-fifth of the Nation's work force;

(8) domestic manufacturers have not sufficiently utilized such recent technological changes in manufacturing as programable automation, robotics, advanced sensors, and computer-assisted design and manufacturing; and

(9) a program to conduct research which will produce more efficient manufacturing processes and methods and to encourage research utilization would strengthen commerce and be beneficial to the Nation's consumers.

PURPOSE

SEC. 3. It is the purpose of this Act to establish a program for conducting research which will produce more efficient manufacturing technologies and for conducting research utilization activities to encourage widespread adoption of these technologies.

DEFINITIONS

SEC. 4. As used in this Act, the term—

(1) "Advisory Committee" means the Manufacturing Sciences and Technology Enhancement Advisory Committee established under section 8 of this Act;

(2) "consortia" means a group of organizations such as States, individual industries or industry associations, nonprofit research institutions, and universities and other academic institutions;

(3) "Center" means a Center for Manufacturing Research and Technology Utilization established under section 5(c) of this Act;

(4) "Office" means the Office of the Assistant Secretary for Productivity, Technology and Innovation within the Department of Commerce; and

(5) "Secretary" means the Secretary of Commerce.

GRANTS AND COOPERATIVE AGREEMENTS

SEC. 5. (a) PURPOSES.—The Secretary, through the Office, may award grants and enter into cooperative agreements in accordance with the provisions of this section to provide for research on methods of producing more efficient manufacturing processes and methods, including—

(1) computer-assisted design;

(2) automated materials handling, processing, and assembly;

(3) automated testing;

(4) machine adaptive learning;

(5) integrated manufacturing systems, including interface of automated machines with automated and

nonautomated machines, with production and design personnel, and with other systems (including testing devices, design systems, and inventory control systems);

(6) machine and process control strategies;

(7) automated sensing for machine and process control and product testing;

(8) practices and activities to implement improved manufacturing methods; and

(9) such other research as the Secretary determines to be consistent with the purposes of this Act.

(b) GRANTS.—(1) The Secretary, through the Office, may make grants to provide for research to increase the amount of fundamental scientific and technological knowledge in fields relevant to manufacturing methods and processes. Such grants shall be made on a competitive basis to applicants who comply with such criteria as are specified in this Act and as the Secretary shall establish, consistent with the purposes of this Act.

(2) A recipient of such a grant may be affiliated with a nonprofit research institution, a private industry or industry association, a university or college, a Center established pursuant to subsection (c) of this section, or any other organization which the Secretary considers appropriate. Any such recipient shall not be required to provide any part of the costs

of such research, unless the recipient desires to expand the scope of the research to be conducted. In such case, the Secretary may enter into an agreement which provides for cost sharing by the recipient.

(3) There are authorized to be appropriated for the purposes of this subsection not to exceed $10,000,000 for the fiscal year ending September 30, 1984, not to exceed $20,000,000 for the fiscal year ending September 30, 1985, and not to exceed $30,000,000 for each of the fiscal years ending September 30, 1986, September 30, 1987, and September 30, 1988. Such funds shall remain available until expended.

(c) COOPERATIVE AGREEMENTS.—(1) The Secretary, through the Office, may enter into cooperative agreements for the purpose of establishing and supporting Centers for Manufacturing Research and Technology Utilization. Such Centers shall conduct research of a more applied nature than the research conducted under subsection (b) of this section. Centers shall study methods of increasing the utilization by the Nation's industries of those modern manufacturing methods which may result in lower production costs and improved product quality and reliability. Such research may be directed toward problems or processes and methods appropriate to a specific industrial sector, including aerospace, microelectronics, mechanical assembly, basic materials, new materials, and transportation.

(2) The Secretary shall enter into any such agreements with consortia of research organizations and manufacturing industries or industry associations. Such agreements shall be made with applicants who comply with such criteria as are specified in this Act and as the Secretary shall establish, consistent with the purposes of this Act.

(3)(A) In addition to funds received under this subsection, a Center may receive funds from Federal agencies and from public and private organizations. Consortia which enter into such an agreement shall provide support and participation in a dollar amount at least equal to the amount of the Federal contribution to be made under this subsection.

(B) For purposes of this paragraph, the term "support and participation" includes cash or equipment contributions in an amount equal to at least 50 per centum of the Federal Government's share, industry personnel to conduct research, and access by persons in the research organizations to modern manufacturing equipment in the participating industry for research and other appropriate purposes. Contributions from nonprofit participants may consist of in-kind contributions. Federal contributions made under this subsection may be utilized only to support expenditures by nonprofit research organizations participating in the relevant consortia.

(4) In entering into such agreements, the Secretary shall consider—

(A) the quality of the research which is to be undertaken as a result of the particular agreement;

(B) the extent of participation by industry in the research to be undertaken as a result of the agreement;

(C) the size of the industrial sector involved and the potential impacts on the productivity of that industrial sector as a result of successful research undertaken through the agreement, as well as the subsequent development and utilization of the manufacturing methods and processes to be studied as part of such research; and

(D) the extent to which entering into the agreement would be likely to increase the number of scientific and technical personnel capable of utilizing modern manufacturing methods and processes.

In addition, the Secretary shall insure diversity among the industrial sectors which are the subject of the research conducted under any such agreement, as well as geographic dispersion of the Centers established and supported under this subsection.

(5) There are authorized to be appropriated for the purposes of this subsection not to exceed $5,000,000 for the fiscal year ending September 30, 1984, not to exceed

$15,000,000 for the fiscal year ending September 30, 1985, and not to exceed $25,000,000 for each of the fiscal years ending September 30, 1986, September 30, 1987, and September 30, 1988. Such funds shall remain available until expended.

ADVANCED MANUFACTURING METHODS RESEARCH UTILIZATION PROGRAM

SEC. 6. (a) ACTIVITIES.—The Secretary shall establish a program of experimental activities, and shall evaluate existing activities, to identify the most feasible means of enhancing the utilization of technologically advanced manufacturing methods by retraining workers who have been displaced from declining industries. The Secretary shall provide for the development, conduct, and evaluation of such experimental activities. The Secretary may, to the extent provided in advance in appropriation Acts, contract with any appropriate person or organization (including States and Centers established under section 5(c) of this Act) to carry out such experimental activities.

(b) REPORT.—Not later than one year after the conclusion of the program carried out under this section, the Secretary shall submit to the Congress a report on such program.

(c) AUTHORIZATION.—There are authorized to be appropriated for the purposes of this section not to exceed $4,000,000 for the fiscal year ending September 30, 1984, and not to exceed $10,000,000 for the fiscal year ending September 30, 1985. Such funds shall remain available until expended.

COMPETITIVENESS STUDIES

SEC. 7. (a) STUDY.—The Secretary shall select specific domestic technology-sensitive industrial sectors and shall analyze such sectors' long-term capability for remaining competitive, especially with industries in foreign countries. In making such selection, the Secretary shall consider industrial sectors which are or are likely to be vulnerable to foreign competition, as well as sectors which are likely to experience rapid and significant growth.

(b) SUBJECTS OF STUDY.—As part of such study, the Secretary shall consider—

(1) the adequacy of technologies utilized to produce the goods and services of such sectors;

(2) superior foreign technologies or unique resources which yield a competitive advantage to industries in foreign countries over similar domestic industries;

(3) the anticipated scientific and technical personnel requirements for such sectors;

(4) the adequacy of Federal laws and regulations, and the enforcement of such laws and regulations, in

promoting technological innovativeness and commercial competitiveness by such sectors; and

(5) whether changes in such laws and regulations, or the enforcement of such laws and regulations, are desirable to promote technological innovation and competition in such sectors and to safeguard the well-being of the Nation and the public.

(c) AUTHORIZATION.—There are authorized to be appropriated for the purposes of this section not to exceed $1,000,000 for the fiscal year ending September 30, 1984, and not to exceed $2,000,000 for each of the fiscal years ending September 30, 1985, September 30, 1986, September 30, 1987, and September 30, 1988. Such funds shall remain available until expended.

ADVISORY COMMITTEE

SEC. 8. (a) ESTABLISHMENT.—The Secretary shall establish a Manufacturing Sciences and Technology Enhancement Advisory Committee to advise the Secretary concerning the activities to be conducted under this Act. The Advisory Committee shall have representation from technology-sensitive industrial sectors, from labor, from the manufacturing research community, and from other sectors which the Secretary considers appropriate. Such members shall be appointed by the Secretary for a term of two years, and shall receive no compensation. Any such member shall, in accordance with section 5703 of title 5, United States Code, be entitled to reimbursement for travel or transportation expenses incurred in the performance of responsibilities as a member of the Advisory Committee.

(b) FUNCTIONS.—The Advisory Committee shall—

(1) review the policies and selection criteria for grants made and cooperative agreements entered into under this Act;

(2) review the progress of the Secretary of Commerce in meeting all the requirements of this Act;

(3) assess the effectiveness of the activities funded pursuant to this Act; and

(4) submit to the Secretary, at least annually, evaluations and recommendations regarding activities carried out under this Act.

(c) REPORT.—The Advisory Committee shall submit to the Congress an annual report on its activities under this Act.

(d) APPLICABILITY.—The Advisory Committee shall be subject to the Federal Advisory Committee Act (5 U.S.C. App. 1 et seq.).

Sec. 5a, Art. 5

(Add). This plan shall be reviewed annually by the governing board described in Sec. 7 and their recommendations passed on to either the NRC or the National Science Board (NSB).

Sec. 5b, Art. 1

(Add). Research that may be performed in this center will be primarily pursued to enhance its ability to satisfy the above mission focus.

Sec. 5b, Art. 3

(Add). . . .to coordinate activities and shall function under the same external review as established for the other centers by the review board described in Sec. 7.

Sec. 7a

(Question ?) Representation on the Board shall be balanced. (What is the meaning of balanced as used here?)

Sec. 7b

(Add). The Board shall select its own chairman. This selection shall be reviewed by either the NRC or the National Science Board (NSB).

Sec. 8a and 8b

(Comment). The funding for Sec. 8b for Education and Training is too small if the programs in Sec. 8a are not also directed to develop manpower through their academic functions.

Sec. 8d

(Comment). The $10,000,000 center for NBS at first glance appears to be too high relative to those for the other centers (probably $3,000,000 each). It may be justified as a budgetary replacement for the program already funded at NBS in robotics. Generally, the $10 million would be approximately 15 percent of the total program. It is suggested here that this program be split in half as $6,000,000 in house work and service in technology transfer and $4,000,000 out to other universities for joint ventures in basic and applied research. In this manner, NBS could more effectively perform the mission described in Sec. 5b, Art. 1. Otherwise, it is suggested the $4,000,000 be moved to the NSF program for centers. There may also be some justification to ramp up this magnitude ($5 million in 84, $7 million in 85, and $10 million in 86) as is being proposed in the other parts of the bill.

B. H.R. 4415: Manufacturing Sciences and Technology Research and Development Act of 1983.

Overall Comment:

This bill is directed to partially solve an increasingly dangerous problem in weakness in the United States competitiveness in manufactures trade. Much of this is due to lack of national purpose and structured response. Unfortunately, relative to the need, this bill is woefully lacking in magnitude. This low level of commitment may in fact suggest that it may be better not to begin any program at all unless it is intended to have a greater role of sufficient magnitude. If our manufactures trade loss is approaching $110 billion for 1984, then an investment of $0.06 billion in this bill represents a level of commitment of not more than 0.05 percent. In fact, a level of effort of 1 percent of this trade loss (or $1 billion/yr.) could easily be defended.

Another weakness of the bill is that diverse groups would be formed without a truly cohesive national strategy. The parts are not designed to form a whole response (without significant voids). This becomes essential if the truly immense breadth of manufacturing is to be addressed. The model of the separate but additive missions of the Air Force R&D labs is a good one to use in order to put this program on a sounder long-term footing.

Finally, it is imperative that the universities play a major role, either as primes or as significant subcontractors to nonprofit labls or to industry. This academic role should be oriented to generate the best possibly quality of expertise in a new generation of manufacturing researchers and engineers. Where this is done on distributed negotiated mutual benefit among the parties, a successful program is much more likely.

Section VII

Next Generation of Technology for Robotics

Missions: Industrial Automation
Energy Systems Operations
Military Operations
Human Augmentation and Agriculture

by

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1983

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I. APPLICATIONS APPROPRIATE TO AN ADVANCED ROBOTICS TECHNOLOGY

This section of the document is intended to list a representative collection of the most demanding and rewarding unmet applications of robotics. In each case, the application is described in terms of its economic merits, its technical feasibility, and its benefits to the user. Also, in each case, some indication is given as to the necessary technological developments required to satisfy the associated application. One of the more immediate technological gaps is associated with the "open loop" operation of all existing robotic manipulators. Because of this inadequate sensing and real-time compensation based on an inclusive dynamic model, it is impossible to maintain spatial coordinate accuracy (with or without external disturbances and loads). Hence many precision operations at small and large scales (micro-surgery, precision light machining, laser welding, etc.) remain unsatisfied. It also means that off-line programming is normally not possible, such that on-line teaching (while no production occurs) is necessary. This means that the data base cannot directly control the robotic system nor support real time inspection. Hence, special precision assembly, clean room operations, micro-assembly and inspection are less likely candidates for robotics. In batch mode manufacturing, this deficiency means the continued high expense and use of numerous machining jigs—a barrier to the factory of the future.

In other applications, the dexterity and obstacle avoidance of existing systems is inadequate. Many of these systems must work in an obstacle strewn, unstructured environment. Here, special sensing and an advanced machine intelligence must enhance the information sent to the human operator at the man-machine interface to augment his judgment and decision making capacity. Time, frequently, is of the essence so that exceeding human operating speeds is highly desirable. Strategy and planning to deploy friendly forces and strategy identification of unfriendly forces sometimes using incomplete data bases or fuzzy data for military operations has yet to be treated as more than a concept.

INDUSTRIAL AUTOMATION

1. Micro-processing is the spectrum of application of robotics to very small scale industrial operations such as wire soldering of leads to micro-chips, visual inspection and repair of very small assemblies, etc.
2. Complex assemblies involves sequential piece assembly within an obstacle strewn environment where perhaps more than one robot would be necessary (i.e., mounting of a shock absorber on a car).
3. Precision light machining refers to lightly loaded machining tasks in thin stock such as routing, trimming, and deburring while maintaining high tolerance without supporting jigs.
4. Welding in ship structures requires the placement of imprecisely cut thick stock in an egg-crate array and autonomously welding the parts in place.
5. Riveting and deriveting of airframes is the semi-automatic procedure of rivet location, rivet removal, hole inspection and refurbishing, and rivet replacement on airframes with minimum human involvement.

ENERGY SYSTEMS OPERATIONS

6. Nuclear fission reactors could be maintained by robotic systems (especially the steam generator) with minimal occupational radiation exposure and an economic benefit to the nation by 1990 of $1.8 billion/year.

7. Nuclear fusion reactors will require a much higher level and more frequent remote maintenance than fission reactors if their availability is to be 75%.

8. Oil exploration and production on the ocean floor involves maintenance and inspection of the complex ocean floor technologies (valves, pipes, pumps, etc.) in an unstructured environment.

9. Coal production is responsible for 200 deaths/year and considerable cost to the nation due to black lung disease, a dilemma that could be reduced by developing a "manless" coal mine.

10. Nuclear fuel handling and reprocessing has been a long time user of robotics and is now experiencing a new level of technological development at the Oak Ridge National Laboratory.

MILITARY OPERATIONS

11. Remote ocean operations concerns the remote surveillance, personnel retrieval, repair and tactical operations in an unstructured ocean environment.

12. Battlefield operations represents a complex of operations such as surveillance, autonomous tanks, mine removal etc. to remove personnel from the war zone.

13. Maintenance and emergency repair technology is intended to remove technically trained personnel from the war zone as well as make emergency repairs more cost effectively and reliably.

14. Fuel and ammunition handling will reduce logistics problems, increase reliability and reduce personnel exposure in the war zone associated with the movement and palletizing of material.

15. Planning and strategy operations will augment the field commander's decision capacity as the complexity of field operations increase and provide him with an assessment of the strategy of the unfriendly forces.

HUMAN AUGMENTATION AND AGRICULTURE

16. Micro-surgery is intended to augment the precision of the surgeon's motor capacity by a factor of 10 and increase his productive life for operations of the brain, ear, eye, nose and throat including exploratory diagnostics.

17. Prosthetics and orthotics suggests that many partially incapacitated human joints and limbs could be either supported passively or actively to provide improved structural function or they could be replaced by advanced intelligent prosthetics.

18. Agricultural operations associated with non-cereal production are labor intensive and frequently under weather threat. Robotic handling and harvesting equipment could not only reduce costs but also reduce production uncertainties.

19. Accident missions suggest using robotic systems in surveillance, people retrieval, and active threat reduction associated with fires, earthquakes, terrorists, and bomb removal and disabling.

20. Training and service robots are intended to augment humans in education at all levels (truck operation to micro-surgery) with future systems developed for cleaning and maintenance in both public and domestic applications.

INDUSTRIAL AUTOMATION

1. Micro-processing

One of the future opportunities for intelligent machines and robotics is the performance of various precision operations at very small scales. Examples involve the mechanical handling of very small electrical components, wire soldering of leads to micro-chips, visual inspection of very small assemblies, and mechanical or electrical (by laser beams) repairs of imperfect components. Generally, as the complexity of computers, avionics, and precision instrumentation increases (including medical instruments), the need for minaturized systems (micro-robotics) will also increase. Autonomous and teleoperator type systems will be necessary depending on whether the operation can be highly structured or will require the judgement and decision making of a trained human operator. This type of technology will make clean room operations increasingly cost effective and more widespread. In order to achieve this level of technology, a generic class of miniaturized bearings (perhaps jeweled), specialized sensors and encoders, and actuators must be developed. Generally, as the scale is reduced, the relative importance of friction increases such that special antifriction measures will be necessary. Also because tolerances will be so small, programming the system by visual inspection will be much more difficult. Consequently, miniature robotics will require a much higher level of machine intelligence than that found in present generation robotic systems.

2. Complex Assemblies

Most assembly processes currently being performed by robots are especially designed to take into account the present limitations of the robot system. For example, the assembly of an electric motor allows a sequential stacking of components about a vertical axis of symmetry. The insertion of electrial components on a circuit board occurs only on one plane within virtually a perfectly rectangular array. None of these operations must occur in an obstacle strewn environment. Furthermore, most of these steps require relatively little force during the joining stage. Hence, they can be classed as precision, unloaded, unobstructed assemblies.

Future assemblies must treat a much broader range of tasks including force fit assembly, fastener deformation, the joining of heavy components, joining of components by single or repeated impacts, etc. Furthermore, as the assembly progresses, access to the work scene will be obstructed either by jigs or the parts of the unfinished assembly. Consider the difficult task of putting shock absorbers on the suspension of an automobile as one of the type of assemblies that must be addressed in order to expand the market of robotics. This expanded class of assembly task will require precision under load (now universally lacking), a very high level of dexterity, obstacle avoidance routines by an advanced machine intelligence, and a combination of sensors and dynamic modeling in real time to "close the loop". This level of technology will require the most of integration of all mechanical and electrical technologies and will require a concerted research and development effort.

3. Precision Light Machining

Batch mode manufacturing implies numerous light machining tasks where high precision and rapid changeover from one task to the next is necessary. Two example tasks are deburring and trimming of surface panels of aircraft. Because of the large deformations experienced by robotic manipulators operating under these machining loads, jigs or fixtures are used to resist these loads. Of course, the jig must be matched in shape to each part to be finished. In batch manufacturing, literally hundreds of parts (and therefore jigs) are involved - hence, the costs of manufacture and handling of these jigs is very high. Other costs are involved. Programming the robot still relies on step-by-step teaching in the work environment which is very time consuming - a time during which no production is possible. Also, the jig interrupts the flow of information from the unit process to the factory computer data base making the factory of the future impossible.

All of these high costs items for robotic systems could be greatly reduced if precision under load could be achieved. The first need is a complete and accurate parametric model of the industrial robot manipulator (rarely exists and certainly is never used in real time operation of today's robots). Next it is required to make real time (1/30 sec. sampling rate) computer control of the robot in terms of this dynamic model a reality. Also, off-line programming must be developed to make the robot absolutely accurate in world coordinates. Finally, the system must be able to eliminate force induced deflections from the machining process by compensating commands to the actuators. All of these technical objectives will require the best machine intelligence based on the most advanced analytical tools from the mechanical and electrical disciplines. This "closed loop" concept is an essential component of the next generation of robot - i.e., the fly by wire robot which may then be considered "electronically rigid."

4. Welding in Ship Structures

Welding is one of the most important joining processes used in the United States where almost 1,000,000 workers claim to be welders. Automation of welding has gradually taken place by using automatic wire feeding and special seam trackers in conjunction with "tractors" capable of following a straight seam. Hitachi of Japan has implemeted a 20 pass weld of a precision cut joint between two pipe sections with a 1" wall thickness. The seam geometry in many applications is far from straight and for thick weldments (above 3/16") it is difficult to maintain uniform seam spacing or seam alignment. This fact is especially true of welding associated with ship hulls. Also, the ship hull is large and appears to have an "egg crate" geometry in much of its multiple wall and multiple cell configuration. This reality makes mobility, dexterity, obstacle avoidance, superior sensing, and high precision essential to a ship welding system. Beyond this, excessive teaching time for such complex geometries becomes a dominant problem of the existing robotic technology. This is compounded by the fact that shipbuilding is characterized by its variety of small batch operations (often unique assemblies) where programming time can represent as much as 90% of the total processing time.

In order to eliminate most of these problems, the robot welding system must be driven from a data base of the ship component being welded. Reference points on the tacked assembly can be used to automatically place the workpiece in the coordinate system of the robot. Then if the robot is absolutely accurate and if the welding process is monitored with adequate sensors (such as vision), the welding procedure can be achieved with virtually no teaching time. Of course the data base must tell the robot where the "obstacles" of the incomplete assembly are and how they change as progress is made. The robot intelligence must be capable of avoiding these obstacles without human intervention. It is also feasible that one robot could be used to place parts in the assembly while the second robot performs the necessary weld.

5. Riveting and Deriveting of Airframes

Hundreds of thousands of rivets are used to assemble the airframe of modern airplanes. Even though special hand held riveters are used effectively, they require a great deal of heavy labor. It has been frequently suggested that robots be used to hold the riveting unit during the riveting process. In order to perform this task, the riveter must be perpendicular to the surface and perfectly aligned with the rivet hole. The surface geometry and rivet array forms a complex spacial geometry which demands that the robot have generic motion capability. Because the riveter is heavy the gravity forces will cause significant deflections. These deflections and those due to riveting forces must be compensated for by an active machine intelligence capable of positioning the riveter accurately in coordinates attached to the airframe. Then and only then can the data base control the robot directly. Otherwise, the robot must be calibrated and taught for each section of every airplane one at a time. Such teaching effort would consume more time and higher expense than the previous manual operations.

Airplanes placed on aircraft carriers experience sea salt corrosion of the rivets making it necessary to derivet the airframe. All of the above requirements apply. In this case, it is also necessary to accurately drill out the old rivet. Teaching the robot is clearly impractical because of all the uncertainties and load variations. An advanced form of closed loop control of a precision robot combined with computer vision could make self-calibration of the robot relative to the airframe feasible so long as the data base for that air frame were available. Such a system would make it possible to derivet the plane on board the carrier or in a remote field operations shop making repair logistics much more economical.

ENERGY SYSTEMS OPERATIONS

6. Nuclear Fission Reactors

There are major economic losses associated with the critical path down time and occupational radiation exposure (ORE) associated with Maintenance, Testing, and Inspection (MTI) of nuclear fission reactors. The total cost of these operations in 1980 was an average of $14 million per plant. This represents an approximate $1 billion cost to the nation. When using steam generator maintenance as a vehicle for analysis, a 70% savings is predicted; i.e., a total national savings of $700 million per year. By 1990, the projected savings would reach $1.8 billion per year. If ORE limits were lowered by a factor of 5 (as has been suggested), these numbers would all grow by approximately 75%.

The present level of manipulator technology is insufficient to perform most of the needed maintenance tasks in a successful and time efficient manner. The present and near term reactor was not designed for remote maintenance thus making the need for a generic maintenance system more pressing. This generic system must be capable of performing a series of up to 25 distinct operations in an obstacle strewn environment with the characteristics of a portable machine shop. The PWR steam generator and the BWR valve have been isolated for immediate application of robotics. Specific component technologies which must be addressed to meet this need are multiple task capability, a high level of machine intelligence, man-machine interface, dexterity and obstacle avoidance, precision and load capacity, and portability and mobility.

7. Nuclear Fusion Reactors

Plant availability of fusion reactors will be closely linked to the effectiveness of the remote maintenance technology to be employed. Many experts believe that rather great technical advances in the technology will be necessary. Princeton's TFTR for example, is planning for an availability of about 2%, but even this has not yet been demonstrated with current technology. The Fusion Engineering Device (FED) of Oak Ridge has set a 50% availability goal. The objective of the planned Starfire fusion utility plant must be 75% availability.

The fusion reactor represents a highly uncertain environment, thus calling for a completely general remote system with advanced machine intelligence and man-machine interface. The most difficult remote task will be the handling of the 400 ton shield sector. The shield frame must be precisely positioned, cut, and welded. The required manipulators must handle loads up to 500 lbs. The large loads combined with the large arm dimensions, place extreme demands on the technology where precision requirements are very high. These projected requirements will not be met by evolutionary development expected from industrial laboratories. A much more complete understanding of the complex geometry and dynamics of the manipulator system is needed to produce these larger maintenance devices.

8. Oil Exploration and Production on the Ocean Floor

At the present time, the majority of operations is carried out by human divers, representing an extremely dangerous activity. The present trend towards deeper open-water wells represents an even more dangerous operation. Operations below 450 meters must be carried out by Remotely Operated Vehicles (ROVs). There are two major limitations in the use of ROVs. Present vehicles are controlled by tethered lines, which become tangled and severely limit mobility. Also, due to the lack of advanced manipulator technology, only simple tasks such as monitoring and inspection may be carried out using ROVs. If the offshore oil industry plans to reach greater depths, an emphasis on improved remote technology is necessary. During the 5 year period (1975-1979), approximately 100 wells were drilled at depths over 1000 ft. Subsea production systems (underwater wells) are used at depths of 2000 ft. The investment for a total operational platform may easily exceed $1 billion.

ROVs can operate at 1/10 the cost of human diver systems primarily because of reduced support facilities and personnel. Also, descents and ascents require long periods and in bad weather significantly increase risks. There are over 140 tethered ROVs in use today. Approximately 30 vehicles have manipulator capabilities. Most of these manipulators cannot perform the highly useful but difficult tasks of welding, cutting, bolting, etc. As the production system evolves it will become more modular (i.e., valve modules, pipe joint modules, etc.) enabling more rapid and reliable replacement by remote systems technology. A comparative increase in the effectiveness of this remote systems technology would yield major economic benefits.

. Coal Production

It appears that significant economic benefit and miner safety would result with the use of remote systems technology in deep underground coal mines. Almost no such remote technology is presently used in underground mines. In other words, very little progress has been made to make coal production possible without the direct involvement of human operators - i.e., the manless mine is a distant possibility. The potential areas for automation and robotics are roof support, material handling, fire control and rescue, and surveillance. Roof-bolting is the most dangerous activity in underground mining, causing 50% of all mine fatalities. The mining industry is five times more dangerous than the average U.S. industry, with about 200 deaths occurring each year. The cost of injuries based on 1974 data, to all sectors of society (industry, personnel, health agencies) was $34 million.

Automation of the coal mine will involve the implementation of several dedicated machines. For example, the continuous wall system represents an annual return on investment from 15 to 23% depending upon the level of automation implemented. The use of remote systems technology will be vastly improved when these dedicated machines will be modularized making maintenance by module replacement feasible. Then robotic maintenance systems can be developed with high mobility for this task as well as that of monitoring and surveillance. This combination would make the manless mine possible and significantly reduce the costs associated with maintaining an environment which is suitable and safe for the coal miner.

10. Nuclear Fuel Handling and Reprocessing

Nuclear fuel handling and processing was the first application of robotic manipulators. The technology was developed from 1945 to 1965 at the Argonne National Laboratory. Many hot cell manipulators are used for this purpose today. An evolving application which is now being pursued is fuel reprocessing at the Oak Ridge National Laboratory. There, a new generation fuel reprocessing plant is being designed for implementation late in the 1980's. Such a system which is made up of literally thousands of components that could fail must be maintained remotely once it starts operation because of the high internal radiation levels. One of the first requirements of the maintenance system is extraordinarily high reliability. Not only must the plant be modular and structured for maintenance, so must be the robotic systems used for maintenance. The robotic system must be moved on tracks anywhere in the plant making effective communication with an external data base difficult. Because literally hundreds of maintenance tasks are involved, a human operator must supervise or manually control the task performance through a highly developed man-machine interface. A new generation of robotic manipulator is being developed for this application as are special interface technologies to the operator (visual graphics, voice commands, force feedback, etc.). The goal is to use an advanced machine intelligence to reduce the burden on the human operator by automating as many operations as possble.

MILITARY OPERATIONS

11. Remote Ocean Operations

The Navy has established a program to meet both tactical and strategic objectives. All indications are that much of this work remains at the conceptual or exploratory stage. One of the first objectives is to perform search and identification of sub-sea systems. Beyond this, the goal is to perform retrieval functions of lost hardware or stricken submarines. Finally, the most demanding task will be associated with anti-mine and anti-submarine activity. In the strategic sense, the laying and maintenance of under-water communication cables and power transmission lines is a very high priority. It is clear, that the operating environment, especially for maintenance, is unstructured and could be necessary at any depth of the ocean. For example, the well understood task of underwater hyperbaric welding can not be performed by the present technology. All present systems are tethered ROV's or self-contained diving chambers (i.e., specialized submarines). Only one of these systems (the ROV ORCA) presently offers the necessary feature of force feedback to the operator or the controlling computer.

Generally, this range of applications will require the most advanced generic robotic manipulator technology possible. A number of the systems must be untethered to be effective. The dexterity, sensing, and precision of these systems must be very well integrated. The man-machine interface question is also of the highest possible importance due to the unstructured nature of the task spectrum. Finally, these systems must operate with extraordinary reliability with time as the essence. Overall, robotic technology within the ocean will require the best of all component and system technologies.

12. Battlefield Operations

The primary objective is to perform rapid advance maneuvers with minimum exposure to unfriendly forces. Several dedicated units such as autonomous mine detection and disabling vehicles, autonomous offensive tanks, etc., will be essential. In addition, battlefield communication line networks must be established and maintained. These functions can be performed autonomously only if a collection of sensors are developed (acoustic, optical, electromagnetic, tactile, etc.) which are field hardened and highly reliable. In addition, computational vision based on stored object knowledge must be capable of recognizing objects. All of this sensory information must be forwarded to an on-board central processor whose machine intelligence is capable of reasoning and developing a strategy for action. This strategy must be carried out with high reliability to benefit friendly forces.

Autonomous systems tend to be operations specific. Therefore, alternatives which allow human intervention by teleoperation should be carefully considered. In this case, precision heavy duty robotic manipulators may become an essential device for disabling unique multi-purpose and mobile mine fields (under enemy control). The same teleoperator system could prove highly beneficial in laying mine fields in or behind enemy lines. Or, it may prove feasible to develop an autonomous roving mine field which would be targeted against unfriendly forces. Overall, the question of artificial intelligence appears to represent a technological gap which must be met for this application.

13. Maintenance and Emergency Repair

One of the basic realities of modern military materiel is that it is complex and must be continuously monitored and maintained. This is especially true of the increased use of electronic components such as avionics. Maintenance and emergency repair requires a highly trained practitioner in order to diagnose and correct malfunctions. Unfortunately, the most pressing (and valuable) maintenance operations occur in battle zones or in remote locations such as on board aircraft carriers. This means that many highly trained personnel are exposed to unfriendly forces.

Two steps can be taken to reduce the exposure to technically trained personnel while at the same time making emergency repairs much more reliably. One of these steps has already been established within the field of avionics and that is self-contained modules that are easily interchanged. This design philosophy must be used on the mechanical system as well. The second step is to make maintenance through teleoperation feasible by deploying a generic maintenance robot system having a precision dexterous manipulator with force feedback to a remote station where the operator works with a multi-faceted man-machine interface. Because emergency repairs may be required due to damage from enemy fire, the task spectrum must be considered as unstructured thus requiring a high level of human judgement and decision making to make the maintenance repair as reliable as possible. Here, the technological gap appears to be a generic precision, mobile robotic manipulator with some machine intelligence supported by a superior man-machine interface.

14. Fuel and Ammunition Handling

In the deployment of tactical units, the fuel and ammunition zones are the most likely targets of unfriendly forces and when hit cause potentially severe destruction. Hence, minimizing personnel in this zone would be a high priority. In addition, during engagement rapid loading of fuel and ammunition is a very clear necessity. The major time element is associated with ammunition loading of such units as tanks. It presently takes 3 to 4 hours to load a tank with its full complement of rounds. It is desired to reduce this to one hour - therefore, potentially doubling the availability of the tank. A recent example of automatically loading an A-10 anti-tank aircraft in 8 minutes relative to a period of 3 hours for manual operation shows that a truly integrated system can reduce loading time by as much as a factor of 20 times.

The envisioned system would employ a heavy duty robotic manipulator to semi-automatically depallet the ammunition and pass it to a transfer device at the manway of the tank. The transfer device would lower the round to a reference rack in the tank from which a dexterous robotic manipulator would take the round. The internal manipulator would remove any "duds" as a first step in the return cycle and take all incoming rounds and automatically palletize them in the tank. The internal manipulator would also be able to take the rounds out of the tank pallets and insert them into the tank gun barrel. This internal system would then make one crew member redundant. The external manipulator would be rather large and somewhat mobile on its own platform. The biggest technological gap would likely be associated with the highly dexterous, high load capacity, precision manipulator (internal to the tank) which should be operated autonomously, especially during maneuvers. Such inclusive technology will require very high integration of some immature but emerging component technologies.

15. Planning and Strategy Operations

Today, planning and strategy development is becoming increasingly important to assist personnel in making short term and long term decisions about troop and materiel movement and deployment. As the number of distinct and sophisticated fighting elements (roving mines, autonomous tanks, controlled electronic barriers, etc.) deployed by unfriendly forces expands, the need for more complicated and more rapid decision making becomes critical. In addition to these managed "obstacles", there are terrain obstacles such as boulders, trees, swamps, and rivers. The obstacle strewn environment is one of the unsolved planning problems facing the robotics research community. Presently, the problem is partially solved by trained personnel on-board the dedicated vehicles (tanks, supply trucks, etc.).

In the near term these tasks could be taken over by teleoperation if the control task is relatively simple and no on-board activity demands human activity. As the task becomes more implicit, because of invisible managed obstacles by unfriendly forces, it becomes more difficult to adequately train the large numbers of personnel required in the field. Hence, in the long term, on-board computers will be required to provide planning and navigation. Planning involves data acquisiton (perhaps fuzzy) to augment an existing data base, reasoning among alternatives (serially or in parallel), accounting for coupling among on-going actions (spatial reasoning) and in process control through monitoring and time efficient up-dating of the planned operation. Navigation accounts for the existing system configuration (geometric status) among stationary or managed obstacles (avoidance strategies) to develop routes (optimal paths) by means of a global awareness. Several important technological gaps exist. Primarily, difficulties arise from fuzzy acquired data or incomplete data bases. Route planning involves one of the most demanding of all optimization problems if the obstacles are numerous or managed effectively by unfriendly forces. Finally, strategy identification through analysis of the "movement of managed obstacles" would prove invaluable to decision makers in the field.

HUMAN AUGMENTATION AND AGRICULTURE

16. Micro-Surgery

Micro-surgery involves the use of a microscope to enhance by a factor of ten the vision of the surgeon. At this point in time, this has been a major advantage in the fields of eye, ear, throat, and brain operations. In addition, much research now involves work with single cells and requires the best available precision in mechanical operations. The primary need demonstrated by this activity is to augment the human operator's motor capacity (i.e., the surgeon's) in order to complement his enhanced visual capacity perhaps by an order of magnitude (by a factor of 10). One of the goals of this type of system is to lengthen the productive life of the surgeon. The other immediate goals of improved precision can be achieved by filtering jitters and oscillations from muscles that over-react under tension and by changing scales of the operation through computer enhancement. Thus far, little has been done to satisfy this need with a flexible all-purpose (generic) system. Miniaturized robotic systems have not experienced much development to-date. Three component technologies are important to this application. First, as the system becomes smaller, friction becomes relatively more important making special frictionless bearings an imperative. Secondly, because the tasks are at such a small scale, special miniaturized force sensors must be implemented to keep the surgeon in close awareness of the operation. Thirdly, the surgeon must work through a superior transparent man-machine interface in order to make him not only comfortable but fully in charge of the process. These component technologies are very demanding, and thus far poorly developed. It is estimated that a major team of researchers would require a decade to implement this technology in clinical operations.

17. Prosthetics and Orthotics

Despite the fact that no method for preventing or curing the many arthritides afflicting man have been found, significant advancements have been made in the past decade toward providing an adequate substitute for destroyed joints. The major improvement in the care of arthritics has been the development of internal prostheses. A nominal number of passive orthotic devices have been developed to act essentially as braces for the weakened human structural system. A major opportunity now exists because of development in robotics and micro-electronics to develop active aids to the human system where the muscular activity is diminished or atrophied. Or it may be possible to replace the function totally by an alternative device. In the first case, the kinematics of each structural element (the knee, ankle, shoulder, etc.) must be examined in vivo to exactly duplicate its residual motion. This data can be used to design and demonstrate a class of actively driven orthotic structures to replace or supplement the existing weakened muscular activity. Such devices could be extremely valuable in training or strengthening muscles that have experienced trauma. In the second case, total replacement by means of an actively powered device (prosthesis) may be necessary. Here remaining muscles can be trained to generate electrical signals to be interpreted by a microprocessor which then would control the actuators of the device. A frequent objective to assist quadraplegics is to implement articulated wheel chairs or roving robot servants. All of these systems must be designed for the lowest possible price, be as light weight as feasible, and be exceptionally reliable. Also, in every case the man-machine interface must be carefully matched to the individual be it kinesthetic, voice, or visual. Indications are that this technology could be pursued vigorously today and satisfying results would be expected.

18. Agricultural Operations

One of the primary problems facing many agricultural operations is the relatively high cost of labor intensive tasks associated with such functions as fruit harvesting. The economic loss of inefficient or untimely harvesting (the weather threat) can be devastating. The alternative pursued today is total plant harvesting where specially bred plants produce fruit that ripens simultaneously thus allowing the plant to be destroyed during harvesting (i.e., as with tomatoes). This may lead to both economic and quality compromises. Hence, it is proposed to demonstrate a new class of agricultural system which is capable of independent action depending on the requirements of the unit operation. This may be illustrated by the example of citrus harvesting. In this case, the ripe fruit can be identified by its unique color (orange) relative to a dark green background. This identification can now be accomplished by computerized vision which would identify the fruit and provide data to the central processor to quantify the location of the fruit. On this basis, a robot arm could be instructed to pick the fruit (a fact confirmed by touch sensors). It is recommended that an array (perhaps 20) of inexpensive modular robot arms be used to perform this function, each moving with relatively low speed. If one failed, it could be temporarily removed without shutting down the rest of the harvesting system. Similar developments could be pursued in greenhouse, packing house, warehouse, cut flower, and packaging operations. It now appears feasible to create a whole new class of technology specifically suited to non-cereal grain agriculture.

19. Accident Missions

One of the unmet opportunities for robotics systems involves rescue and surveillance activity associated with accidents such as earthquakes, fires, terrorist bombs, etc. Recently, New York City and several other cities have employed a roving robotic system to remove or disable terrorist bombs. Each year, many police personnel are injured or killed from bomb explosions. Also, in pursuit of dangerous criminals, police frequently have to expose themselves to attack during surveillance or apprehension. In the case of fires, firemen must make every effort to determine the whereabouts of trapped individuals in an on-going fire. Fire resistant robots could be of real value in this surveillance function as well as providing sustenance (food, water, oxygen) or protective cover (fire retardent clothes) to those trapped. Earthquakes require special material handling needs to uncover persons trapped below ruins.

All of these applications require various levels of mobility, sensing, and on-board intelligence. The robotic manipulator itself may be either simple or heavy duty depending on the application. In disabling bombs, the dexterity and visual and force feedback to the operator at a remote location will have to be of the highest order so that accidental activation of the bomb triggering device can be prevented. For fires, it may be necessary to have the device climb the sides of buildings in order to gain access to upper stories of buildings. The robot could carry a lightweight cable which could be anchored on both ends. Then a powered trolley could travel along the cable to rescue trapped individuals. It appears that accident mission robots could have an enormous impact in life threatening accident situations.

20. Training and Service Robots

A future opportunity for robotic technology will involve human augmentation in the broadest possible sense. One of these functions will involve training objectives as now being demonstrated in ground based training systems for the beginning pilot. Here, the system duplicates the flying cockpit environment as accurately as possible including visual and motion feedback to the operator. Similar training systems will be of high economic importance where the actual system (say the operation of trains, large trucks, ships, nuclear reactors, surgery, etc.) is either too expensive or too dangerous to duplicate in reality. In educational institutions, at all levels, robotic technology will be used to enhance functional learning (as now being gained from computer games). Presently, only the simplest digital or analog interface is being used. As an inexpensive man-machine interface becomes more universal, this educational opportunity will rapidly expand.

Service robots have long been envisioned by science fiction and a few elementary examples have begun to appear. None of these systems are known to perform useful work economically. The cost of such systems could easily exceed $100,000. If one considers the functions that would be attributed to a "housebot" one quickly realizes how many unique operations would be necessary. It is conceptually possible to create an autonomous robot vacuum cleaner. This device would carry rechargeable batteries (to be automatically plugged in on demand), be highly mobile, and be able to plan a complete traverse of open floor space while avoiding all obstacles. It appears such a device would have several simply articulated vacuum arms enabling access below furniture and in narrow volumes between obstacles. Eventually, this market will be met but, in the near term, only specialized systems of high value (supermarket floor cleaners) should be attempted.

II. MATRIX OF COMPONENT TECHNOLOGIES FOR ROBOTIC SYSTEMS

The integration of numerous technologies is one of the fundamental realities of robotics (or more generally intelligent machines). Often significant progress in the system development will occur after a breakthrough in a component technology. Hence, except for exceptionally large research facilities, most research efforts will pursue a few component technologies and look to the manufacturer to do the system integration and development. The following 14 component technologies are given to cover the broad spectrum represented by robotics. Each of these component tecknologies will be described briefly in the next few pages.

1. The structural geometry of the robot, its design and operation for determination of its workspace, reach, dexterity, obstacle avoidance, etc.
2. Structural dynamics of robot systems for modeling of robot dynamic and vibration phenomena for purposes of design and improved operation.
3. Prime movers are the muscles of the manipulator whose precision of operation is dependent on their response and resolution.
4. Actuator modules involves the structural integration of prime movers into modules of 1, 2, or 3 degrees of freedom which can be assembled into a robotic system.
5. End-effectors are the interface hardware and software to perform the handling, inspection, machining, etc. task of the robot; they may include special touch and force sensors.
6. Graphics/CAD of robot phenomena to enhance interactive design and optimization in complex manufacturing environments.
7. Sensor technology is essential to the existence of an intelligent machine so that it is aware of its own existence and process parameters associated with its operation (manufacturing, maintenance, etc.).
8. Vision is the specialized sensor capable by computer enhancement of rapidly digitizing the physical environment of the robot allowing for comprehensive planning and strategic operation.
9. Artificial intelligence structures the decision making process for multi-layered phenomena in the robot system.
10. Intelligent control involves the layered implementation of various control strategies on global and local objectives.
11. Software modules implies the compact and hardened packaging of frequently used algorithms and their specialized chip assemblies.
12. Computer architecture involves the assemblage of serial and parallel processors capable of treating multi-faceted computational tasks within the concept of real-time operation of the system.
13. Communication interfaces involves the structural distribution of operational decisions and data reduction and transfer of the sensor signals among the various components and layers of the total system.
14. Man-machine interface allows direct human communication with the intelligent robot to allow human augmentation in unstructured task applications (micro-surgery, nuclear reactor maintenance, etc.).

TABLE 3: ESTIMATES OF LONG TERM IMPORTANCE OF COMPONENT TECHNOLOGIES FOR VARIOUS APPLICATIONS

Estimates of Importance of Robotic Technology for Various Applications Robotic Component Technology	Average	Micro-Processing	Assembly	Light Machining	Welding	Riveting	Fission Reactors	Fusion Reactors	Oil Production	Coal Production	Fuel Handling	Ocean Operations	Battlefield Op.	Emergency Repair	Ammunition Handlg.	Strategy Develop.	Micro-Surgery	Prosthetics	Agriculture	Accident Missions	Service Robots
1. Geometry (13)	3.8	3	4	3	5	4	8	8	4	3	3	6	5	4	4	–	4	2	2	3	2
2. Dynamics (14)	3.4	3	5	5	4	4	4	4	4	3	3	4	4	4	5	–	3	2	4	2	2
3. Prime Movers (11)	4.3	4	3	8	4	6	6	6	5	4	5	6	6	5	5	–	3	2	3	3	2
4. Actuator Modules (10)	4.3	3	4	4	4	7	7	7	5	4	5	7	6	5	5	–	3	2	3	3	3
5. End Effectors (9)	4.4	3	4	2	2	3	5	5	7	4	4	7	6	6	4	–	4	2	4	7	7
6. Graphics/ CAD (12)	3.9	4	4	3	5	5	6	6	4	3	4	5	6	4	4	4	4	2	2	2	2
7. Sensor Technology (5)	4.7	7	4	6	5	5	5	6	5	4	4	6	5	5	3	–	6	4	8	4	4
8. Vision (2)	5.8	9	7	4	5	8	5	5	6	4	3	8	7	4	5	–	6	–	5	3	8
9. Artificial Intelligence (4)	4.8	5	4	4	4	4	5	5	5	4	3	6	6	4	4	10	3	4	4	6	6
10. Intelligent Control (7)	4.7	7	7	8	6	7	6	6	5	4	4	4	5	4	5	–	5	3	3	4	4
11. Software Modules (8)	4.4	5	4	6	4	5	4	4	5	4	3	4	4	4	4	8	5.	4	3	3	3
12. Computer Architect. (3)	5.1	5	6	10	7	8	4	4	5	4	4	5	8	3	4	8	4	2	4	3	5
13. Communication Interfaces (6)	4.7	4	4	5	5	6	5	5	5	4	4	5	8	6	5	–	4	2	4	4	4
14. Man-Machine Interface (1)	6.4	5	3	3	5	6	10	10	8	5	8	8	4	8	3	–	10	10	8	8	7

TABLE 4: VALUE FOR NEAR TERM IMPLEMENTATION OF COMPONENT TECHNOLOGIES

Robotic Component Technology	Normalized Availability	Average for all Applications	Industrial Automation	Energy Systems	Military Operations	Human Augmentation and Agriculture
1. Geometry	1.0	3.8	3.8	5.2	4.8	2.6
2. Dynamics	0.3	1.0	1.3	1.1	1.3	0.8
3. Prime Movers	0.7	3.0	3.5	3.6	3.8	1.8
4. Actuator Modules	0.4	1.7	1.8	2.2	2.3	1.1
5. End-Effectors	0.3	1.3	0.8	1.5	1.7	1.4
6. Graphics/ CAD	0.7	2.7	2.9	2.9	3.2	1.7
7. Sensor Technology	0.6	2.8	3.2	2.9	2.9	3.1
8. Vision	0.2	1.2	1.3	0.9	1.2	1.1
9. Artificial Intelligence	0.2	1.0	0.8	0.9	1.2	0.9
10. Intelligent Control	0.3	1.4	2.1	1.5	1.3	1.1
11. Software Modules	0.1	0.4	0.5	0.4	0.5	0.4
12. Computer Architect.	0.4	2.0	2.9	1.7	2.2	1.4
13. Communicat. Interfaces	0.5	2.3	2.4	2.3	3.0	1.8
14. Man-Machine Interface	0.5	3.2	2.2	4.1	2.9	4.2

Of course, all of these component technologies are of primary importance to the implementation of robotics to this spectrum of applications. Nonetheless, a great deal can be learned by ranking the technologies with respect to their near term and long term relative significance. The long term importance of a component technology should act as a guide to the relative emphasis in basic research among the various technologies. By comparison, the near term value of a component technology should provide an indication of the relative development effort now likely to result in the best short term "pay-off" in actual application. The results of an attempt to quantify these two levels of significance are given in the following partial tabulation.

Normalized Long Term Component Importance		Normalized Near Term Component Value	
Man-Machine Interface	10.0	Structural Geometry	10.0
Vision	9.0	Man-Machine Interface	8.5
Computer Architecture	8.0	Prime Movers	8.0
Artificial Intelligence	7.5	Sensor Technology	7.4
Sensor Technology	7.3	Graphics/ CAD	7.1
Intelligent Control	7.3	Communication Interfaces	6.0
Communication Interfaces	7.3	Computer Architecture	5.3

Note that for the two application groups, military operations and energy systems, the two component technologies, actuator modules and end effectors, show high long term significance.

The difference between the near term and long term rankings is due to the fact that the technologies are not uniformly available in the near term where it is assumed that they will have the same availability in the long term. In this case structural geometry is thought to be 50% available, prime movers and graphics/CAD at 35%, while vision and artificial intelligence are considered to have reached only 10% of their real potential.

1. Structural Geometry

The analytical tools to treat the operation and design of the geometric dimensions of robot arms has been found to be one of the most complex problems associated with robotics. The cartesian robot contains no fixed dimensional parameters. Many present dexterous arms (similar in proportion to the human arm) contain two fixed dimensions. The most general 6 degree of freedom arm would contain 18 design parameters all of which should be evaluated to enhance the reach, dexterity, obstacle avoidance, etc. potential of robot arms. Recently, researchers have shown that the complex mathematical control equations may fail frequently and cause disconcerting disruption in the smooth or precise operation of the arm. Future arms will be a balance among the number of degrees of freedom (redundancy of 2 to make an 8 DOF arm) and the level of complexity in the geometry and the associated planning and control algorithms. Almost all existing arms are now serial devices (one link, one joint, one link, etc.). Future geometry will involve the study of parallel structures for enhanced precision and load capacity. The scale of these devices could become very small (miniature manipulators) putting increased demands on the analytical theory and design methodology. Finally, two or more robots could work together to perform an assembly task (say welding). In this case, what is their common workspace, dexterity, and operating region without mathematical uncertainties or special locking configurations? What is the desirable balance of complexity among the interacting arms?

2. Structural Dynamics

Most existing industrial manipulator arms are very flexible and easily deform under load (from 0.2" to 0.4") and respond to simple hand shaking at frequencies less than 10 CPS which means that their fastest cyclic speed would not be better than 30 RPM (compare with most packaging machinery at 300 RPM and some textile machines at 3000 RPM). The associated deformation may be the result of dynamics of the system (usually known) or they may originate from the task operation (routing, force fit assembly, deburring, etc.) which are usually unknown. Many of these future applications of robotic manipulators will require a high level of precision under large load variations. Today, all manipulator systems operate open-loop where neither the dynamics nor the external loads are accounted for. The barrier to meeting this fundamental objective is the ability to create the model in real-time (say about 30 hz). Having the model in real-time would enable the compensation for the system deformations and predicted improvement of precision under load by a factor of 10. As this technology becomes available, more robust control strategy will be implemented to allow lighter weight structures (especially desirable in serial arms). Also, as improved dynamic control occurs, redundant degrees of freedom will be used to enhance controllability. Alternatively, the dynamic modeling could be made more accessible to real-time operation if parallel structures were used. Associated with this activity is the dynamic programming of the end-effector motion to reduce command shock induced oscillations. This objective is closely related to the desire for high speed "slewing and touching" in minimum time. None of this activity can move forward without accurate parameter identification for the link masses, link deformations, actuator control circuit parameters, etc. As many as 130 parameters are involved. Hence, it will be essential to develop design tools and criteria for these lighter and faster arms.

3. Prime Movers

The muscles or energy sources which move the manipulator arm are the prime movers of the system. These components may be electric, hydraulic, or pneumatic. Electric prime movers are increasingly more common. Because of their inherently low load capacity, they almost always require mechanical force amplifiers in the form of gear trains or metal tapes. These amplifiers all add weight, compliance, and backlash, and they increase maintenance and reduce reliability. Hydraulic prime movers, although powerful, exhibit limitations such as fluid leakage (critical in some clean room operations), sensitivity to dirt in the fluid passing through delicate servo-valves, stiction, and variable bulk modulus in the fluid circuit. Pneumatic actuators are inordinately "soft" and very difficult to control for precision positioning under load.

New electric prime movers are appearing (based on rare earth materials) with increasing load capacity and therefore reducing the critical parameter of weight. Amorphous materials (powder metallurgy) may significantly reduce hysteresis losses having the same effect. Better control through PWM of DC motors based on V-MOS technology and hybrid implementation of digital and analog designs should provide enhanced load capacity, dynamic response, and resolution. Antagonistic impulse control circuits may soon be developed with "cross-firing" to further improve positional resolution. Miniaturized prime movers are one of the critical unmet needs required to drive improved robotic hands or micro-manipulators suitable for micro-surgery, micro-assembly, and small scale inspection and maintenance. At this scale, positional resolution degrades rapidly due to the increased relative significance of friction.

4. Actuator Modules

Modularity of the prime mover and its surrounding physical structure is perceived as a major opportunity to reduce the 6 to 7 year design-to-market cycle time now required for new generations of robotic manipulators. These modules (or building blocks) would be a series of 1, 2, or 3 degree-of-freedom (DOF) units which could be assembled rapidly by a designer to respond to the requirements of a given application. Such modularity would do a great deal to increase the breadth and rapid diffusion of robotic systems.

Most actuators presently being used in manipulators are off-the-shelf prime movers not specifically designed for precision control of large coupled motions as occur in robots. This approach does not lead to an optimum balance between the best characteristics of the prime mover and the physical structure of the system. Presently, many actuators are too heavy, have poor response times to commands, generate backlash inaccuracies, have poor resolution, are not stiff under load, and do not contain any local intelligence. The next generation of robot must be constructed from a large class of near optimum actuator modules which contain their own sub-systems for sensing and intelligence. These modules must be rapidly scaled (small and large sizes) with standard physical and software interfaces for effortless assembly. Enhanced maintenance due to this modular design is an obvious benefit. This approach is the primary reason that the application of the modular micro-chip is so widespread.

A manufacturer has recently announced a 3 DOF hydraulic wrist. Cincinnati Milacron has aggressively implemented their three-roll wrist. A Japanese painting robot uses a sophisticated linkage based 3 DOF wrist of high dexterity.

The human system is composed of a 3 DOF shoulder, a 2 DOF ankle, a 3 DOF wrist and forearm, a 2 DOF knuckle, and a 3 DOF hip. These systems are capable of high positional resolution because of muscular antagonism, therefore eliminating backlash. Friction at very small scales can be reduced by using anti-friction ceramic bearings. Parallel linkage structure can be used in the module to create very high stiffness with low weight. Hence, it can be argued that the next generation of robotic system will come a great deal sooner if a major thrust for structural modules were pursued.

5. End-Effectors

End-effectors are the tools attached to the end of the manipulator arm to perform specialized functions such as welding, drilling, locking or unlocking bolt assemblies, etc. Frequently, specialized tools must be interchanged, a process which must be time efficient and very reliable. Some end-effectors are multi-purpose devices in the same sense that the human hand is able to hold a hammer, screwdriver, or other handtool. Generally, the complexity of the terminal device is an inverse function of the complexity (or dexterity) of the arm. As the technology matures, it is expected that general purpose terminal devices (hands) will reduce demands for versatility on the manipulator arm. I.e., small end-effector motions (in the form of a 3 DOF to 6 DOF micro-manipulator) will make large system motion less necessary.

The normal medium size gripper of today is a simple pair of parallel fingers capable of holding a 5" weight of 10 lbs. Generally, these devices are clumsy and require excess maneuverability to grasp a generic object. Frequently, they incorporate some elementary force and proximity sensing. Specialized end-effectors for drilling, sanding, painting, etc. will continue to be developed. All indications are that a new generic hand is required to reduce the number of special tools necessary to perform a range of unstructured tasks. This hand should have 3 or more compliant coordinated fingers of medium dexterity with good incremental force sensitivity capable of grasping and orienting an arbitrary object in space. The power source and intelligence for this generic hand should be contained within the unit itself because of the difficulty of passing control forces through the wrist of the manipulator. Leakage of hydraulic fluids would limit the usefulness of such a hand. Hence, miniaturized prime movers must be developed for this application. The fingers for this generic hand should employ a robust, low hysteresis touch sensor with 1 gram sensitivity and a dynamic range of 1000 to 1. The desired resolution would approach 1000 points/in.^{2} Preferably, the sensor would process this force data locally at the sampling rate of 100 hz. Once the technology for such a hand has been demonstrated, it will be necessary to fill out the spectrum between it and the specialized devices prevalent today.

6. Graphics/CAD

Because of the generality of motion during operation and the large number of system design parameters, the design of manipulators is an expensive, time consuming and challenging task. The magnitude of this task can be illustrated by noting that a generic six degree of freedom serial manipulator can have as many as 18 geometric parameters, 60 mass parameters, and 42 stiffness parameters along with 12 or more actuator parameters. The design and development of such a generic structure can cost millions of dollars (the space shuttle manipulator cost $100,000,000 to develop). As requirements for precision operation, cyclic speed, and external loads increase, the ability to meet complex design objectives becomes more critical. In order to provide enhanced system design and expand the designer's understanding of and control over the design process, it is essential to utilize rapidly growing computer capabilities and availability of computer-aided design and engineering (CAD/CAE). Efficient computational tools developed in this effort can also lead to improved manipulator control algorithms which consider how the effective stiffness, strength, and speed characteristics vary throughout the workspace. For example, no known method exists to analytically distribute the actuators along the manipulator arm with regard to load capacity, spring stiffness, speed of response, etc.

Supporting this effort must be an effective graphics feedback structure to the designer. The mathematical analysis of robotic manipulator mechanisms leads to intricate vector relationships which can not be visualized without graphic assistance. The problem of rendering prismatic, pyramidal, and spherical objects must be solved in real-time as a three dimensional image. Since the functional relationships are known to be highly non-linear, typically dominated by long strings of trigonometric operators, tabular decision rules may be necessary. Specialized hardware may be necessary to calculate the required rotations, translations, and scaling (preferably within nanoseconds). Coloring can be used to provide visual clues for local deformations, actuator load demands, actuator response demands, vibration modes, etc. Given the existence of this technology, it would then be feasible spatially to integrate robotic manipulators in a work cell, to sequentially monitor an assembly process from beginning to end, to study the spatial interaction of two manipulators, etc. to train an operator of a robotic work cell, etc.

7. Sensor Technology

For robotic systems to become more intelligent, they will require a wider spectrum of precision sensors such as proximity, range finding, position, touch, etc. Modern electronic technology has established fabrication techniques at small scales that can be applied to the development of new and/or greatly improved sensing elements. Force sensors deserve special attention because of their irreplaceable role in man-machine communication and enhanced machine intelligence. Integrated strain gauge elements and piezo-resistive films can be deposited directly on compliant structural elements to generate signals to be interpreted by local VLSI electronics. The scale of such devices must match the scale of the task spectrum of the robot. Industrial robots involve force levels of 5 to 150 lbs. and must provide high reliability with minimum compliance. For miniaturized systems, a range of a few ounces and a relatively higher compliance would prove acceptable. Today, exceptionally few such devices are employed, indicating that robotic systems operate at a very low level of intelligence.

Progress has been made on joint position encoders where angular resolution of 20 to 21 bits is now feasible (1 part in a 1,000,000 or 1 arc second) but at high cost ($10,000) and size. Some industrial applications would warrant this resolution when specified end-effector accuracy approaches 0.001 inch. Force sensors of 50 lbs. maximum load and 1 oz. resolution have been developed and are being marketed for approximately $3,000 to $8,000. In themselves, neither of these systems are sufficient to accurately locate the end-effector in world coordinates. The primary dilemma for sensing to-date is that accurate data on the spatial location of the end-effector (and the rest of the arm as well) without using sensors attached to the arm structure (which introduces deformation errors, noise, and great complexity) remains essentially impossible today. Some acoustic and laser range sensors are known to have resolutions of 1 part in 1000. The resolution of the laser range finder would be enhanced by retro-reflectors on the end-effector. Concepts of optical triangulation, structured light, and laser interferometry have been brought forward to meet this problem. Not only must line of sight be preserved but high speed data reduction would be essential. The lack of this type of technology means that adequate compensations for target deviation is not possible. Hence, robots cannot be taught off-line to do precise operations which implies that the data base of the factory of the future is of nominal value. A solution to this problem would represent a breakthrough in robotic system control and therefore a much broader range of useful applications.

8. Vision

Vision has long been perceived as an important information feedback technology for intelligent machines. With human operators in the control circuit, the use of vidicon cameras is common. These cameras are now available at 2/3 inch diameter with 600 lines of resolution and 5 lux intensity. Solid state cameras are now able to match these properties. These cameras can now display up to 800 by 800 pixels at 2,000 frames per second. Some of the systems can display up to 64 gray levels (only one is known to display color). The primary barrier to the application of solid state cameras for autonomous operation is that scene quantification of visual shape data is very time consuming for the computer system.

Consequently, much of the development effort in recent years has been targeted towards meeting simple scene analysis useful for gross positioning of planar objects or the inspection for salient features such as holes and edges. In the United States, 60 to 80 companies are now offering image analysis systems. Of these, 20 are dealing with complex vision tasks. The most common technique is image or template matching by means of feature extraction (edges, curvature of edges, area moments of inertia, number of holes, array configuration of holes, etc.). One recent offering uses parallel processing and pipeline architecture to treat 350 planar images/sec. with 64 gray levels in "nearly" real time. Another company uses training in terms of a known object using gray scale, textures, color, and light intensity in a combined recognition scheme. Finally, structured light has been used by one firm to check 1250 dimensions on an engine block to a tolerance of 0.015" accuracy over a time period of 35 minutes. The cost of the system could exceed $200,000.

Present vision systems appropriate for integration in robotic systems have a resolution of 1 in 200 or 0.5%, far below that required for tolerance inspection and approximately one order less than the positional resolution of recent precision arms. The number of objects that may be analyzed in the scene is limited by the computational speed of the processor. Further limitations are: required dedicated lighting (preferably as a silhouette), vertical viewing above the planar surface, and limited overlap of the objects. Uniform agreement centers on the need for processing speeds to be increased by two or more orders of magnitude which is probably only feasible by specialized parallel processing architecture or special chips specifically designed for feature enhancement (such as edges). Computational vision becomes more important as the task becomes less structured which implies the need to treat 3-D objects in a generic fashion using color, texture, surface normals, binocular vision, etc. A combination of knowledge base and extremely high speed computation appears to be the only feasible means of achieving real time visual feedback.

9. Artificial Intelligence

Artificial intelligence represents the highest level of decision making required of complex autonomous or semi-autonomous systems such as robots. Machine intelligence implies the implementation of artificial intelligence (decision making) in the operational software of robots. A broad thrust in machine intelligence development is underway in the robotics research community as represented, for example, by several operational robotic manipulator control languages. The overall goal is to create the best structure for the complex layering of performance criteria in coordination with operational means to satisfy some functional task. One facet of this effort is optimal control of multiactuator systems, general path planning, and navigation in terms of imperfectly quantified and statistically changing parameters associated with robotic manipulators.

One of the first steps in treating a complex system is the establishment of a world model which includes the knowledge base, state of the task, expectations based on experience, task times, history of the system degradation, potential obstacles to success, etc. Associated with the world model, is the layered task decomposition of the system operation (i.e., plant—planning, shop—resource allocation, cell—inventory, station—parts handling, machine—part processing procedure, task—motion planning, trajectory—motion control, tolerances—sensor and actuator commands). Optimal task decomposition implies that equal portions of the system's resources are applied to each task level. System operation that is in good agreement with the world model is continued. Otherwise, poor results suggests that this experience should be used to change the world model and the system operation. This may also mean a new task decomposition to better allocate internal resources relative to bottlenecks in the flow of input information (from sensors) or the flow of command information (from processors). As the world model and the balance of task decomposition improves due to experience, the level of internal decision making should diminish and the speed and reliability of this decision making should be enhanced. Research on artificial intelligence should first be pursued in terms of a well defined system having easily measurable performance objectives. Rule-based reasoning can then be used to adapt the artificial intelligence model to the realities of the actual system. This improved world model for AI could then be used to adapt other AI models based on imprecise internal definition and/or fuzzy performance criteria.

10. Intelligent Control

Here intelligent control is intended to mean the global and local control of the system's operation to meet established performance criteria. Status information comes from a series of sensors (tactile, force, visual, etc.) and the data is reduced and interpreted by either distributed or central processors. This interpretation yields command signals to the actuators to carry out the desired operation. One objective is to make the manipulator "electronically rigid" in order to resist all work forces with effectively no deformation and therefore superior precision. Another objective is to make the arm "electronically massless" in order to make system response to commands extremely rapid such that high cyclic speeds can be achieved. A third objective is to make the system parameters "electronically constant" so that system operation, once perfected, would remain invariant. Another representative objective of intelligent control is enhanced smoothness of the prescribed motion in order to reduce shock induced oscillations in the physical structure of the manipulator.

Precision under load is not feasible with today's manipulator technology. In addition to real-time dynamic modeling, a new type of distributed control will become essential in order to provide precision under load. Essentially, the large system motion is too highly coupled and non-linear to respond to sensory data involving deformations occurring at a much smaller scale. Hence, a new layer of control software and hardware must be developed to treat this small scale function.

Vibration oscillations is the principal limiting factor preventing increased cyclic speeds. Experience with mechanical systems indicates that such oscillations are usually generated from shocks in the command signals. This means that the simplistic start-stop (bang-bang) control of some systems is the worst possible approach. Generalized motion programming synthesized to enhance the smoothness (shocks occur only at the higher derivatives) is now being developed based on the wide experience derived from the programming of read only memory machines such as cams.

Industrial robots do not exhibit perfectly invariant parameters within the complex control and structural subsystems. The sources of the parametric variations may come from changes in actuator electrical resistance (or hydraulic fluid temperatures), friction in joints, dimensional changes due to temperature fluctuations, etc. Implicit parametric variations may also be due to imperfect numerical values used in the deterministic model. The objective would be to characterize these parametric variations and to develop a self-organizing adaptive system to compensate for these variations with reference to the nominal deterministic model. Such a self-calibration system has recently been demonstrated to maintain positional accuracy of an assembly robot.

It is expected that the most advanced level of intelligent control will involve integration of AI principles for perception, feature extraction, image recognition and cognition. This advanced robot control will include unmanned decision making, planning behavior, interaction with other robots, and interface with human operators. AI enhanced control will structure the motion trajectory, timing, avoidance of "obstacles", navigation, strategy, experience driven learning, and lead to a form of anthropomorphic intuition. The actual control of a complex multi-actuator system can only be achieved by voltage commands to and feedback gain adjustment of the actuators themselves. Today, limited success in this final step has been achieved. Intelligent control at this level will be the result of a merger of AI and modern control theory integrating the advances for stochastic and non-linear systems as well as self-organizing and learning adaptive techniques.

11. Software Modules

Clearly software is a critical operational ingredient for robotic manipulators. Thus far a few languages for system control have been developed primarily to enable positional programming and control of the system. As the desired performance of robots is expanded, they will necessarily become more sensor based and more intelligent. But this intelligence will involve an increased level of software. As suggested for actuator modules, the software system will be more rapidly developed and diffused if it is modularized. Then, the system designer will be able to more rapidly assemble a total software package from perfected modules that can be easily debugged or replaced with more effective units when they become available. Such modules could be designed to operate at the highest available sampling rates in hardware dedicated to the software module. Since such modules would be widely used, the associated hardware would become much less expensive.

Appropriate candidates for software modules are associated with smart sensors, prime movers and actuators, end-effectors, and vision. Other modules would depend on the task decomposition of the system. Each task level would involve sensory data from below interpreted by the module combined with commands from above to generate commands to send down and to generate a higher level of information to pass up to the next level. Disturbances or new "world" information could enter horizontally at each task level. At each level several sources of sensory information from below would have to be integrated while the command signal would have to be passed to the lower level. Thus a generic control structure could be used at each level. The format, sampling rate, and quality of information would be dependent on the height in the hierarchical tree. The total computation effort per hierarchical module would be kept as constant as possible to reach optimum results.

12. Computer Architecture

The growth of the field of micro-electronics is the primary reason that accelerated development in robotic systems technology becomes feasible today. The goal is the distribution of micro-electronic hardware modules throughout the system (distributed intelligence) in order to make smart sensors, smart actuators, etc. Because these hardware modules are each dedicated to a unique task, the calculations could be made more rapidly in special high speed arithmetic processors. Another opportunity is the trade-off between computational speed and precision for robotic motion. The model is based on CORDIC perhaps best known for its use in hand-held calculators. Basically, the process is an iterative procedure for function evaluation (such as trigonometric functions) where with each iteration, additional precision is obtained. Hence, speed and accuracy are natural trade-offs in this process. In robotic systems, precision is usually required at only a few positions in the cycle. The required equipment would involve only standard firm ware components, notably bit-slice processors and high-speed look-up tables (ROMS). For example, the TRW 24 x 24 bit multiplier chip can be used to multiply two 32-bit floating point numbers in 200 nanoseconds. This speed is 400 times faster than the fastest multiply statement executed on the DEC PDP 11/23.

One of the primary problems limiting progress towards real-time operation of intelligent robots is that existing serial processors are poorly suited to treat the fundamentally parallel nature of the phenomena of robotic manipulators. For example, future systems may involve many sensors generating a large information array all of roughly equal significance to the system. This reality of excess data, all at the same level, has been adequately demonstrated for machine vision. It is much less well understood with regard to the real time operation of the dynamic model of the manipulator system. There are six distinct computational levels which must be implemented serially. Within each of these levels 100 to 800 distinct independent functions can be calculated in parallel. This massive functional parallelism shows that parallel processing is essential for the real time control of any system having the geometric complexity of a general robotic manipulator. As mentioned for spatial end-effector position sensing, an economical parallel processing architecture would represent a break-through for the next generation of robotic system.

13. Communication Interfaces

Many practitioners in robotic implementation have discovered communication mis-matches between system components (primarily at the machine level). However, as the data base of the factory of the future becomes more addressable, the need for very highly integrated communications will become imperative. Since no one manufacturer will supply all factory units, standardized interfaces will become very desirable. At the other end of the spectrum are the interface needs between robotic components such as sensors, actuators, distributed processors, etc. Some of the issues are voltage levels, rates of sampling, numbers of channels, multiplexing, AD-DA converter technology, scaling, synchronization, error filtering, noise reduction and isolation, and data compaction. Obviously, both hardware and software issues are involved. The goal must be to standardize as many of these interfaces as possible. The National Bureau of Standards robotics program is pursuing this objective as one of their major missions. The Navy is working on ways to establish accurate long range communication with untethered vehicles in the difficult medium represented by ocean sea water which contains debris. In the Oak Ridge National Laboratory fuel reprocessing plant development, tethers would drastically limit mobility of the maintenance and handling equipment. Hence, special frequency radio wave systems are planned to ensure complete mobility.

14. Man-Machine Interface

Almost all of the development work now being pursued in the U.S. deals with autonomous machines. This approach assumes that artificial intelligence can be transformed into an operational machine intelligence capable of duplicating or exceeding the judgement and decision making capability of the human operator. For repetitive, and highly structured tasks as occur in simple manufacturing processes (pick-and-place, spot welding, spray painting, etc.) this is possible. For tasks such as complex assemblies, nuclear reactor maintenance, or avoidance of maneuvers of an intelligent enemy, the required level of intelligence does not appear to be feasible in the next two decades. The best near term opportunity is to use a balance of human and machine capabilities. As the machine technology improves, less will be asked of the human and more of the machine. This man-machine approach allows the most rapid penetration of the manufacturing market with near-term technology, allows a gradual and natural transference to more machine-oriented systems, and allows a minimum disruption of the manufacturing workforce.

The objective is to develop a transparent and universal interface between the human operator and the robotic manipulator. Commands to the manipulator from the human must be made in the most natural manner (voice, digital, or kinesthetic) and must occur with a minimum burden on the operator. Force feedback is critical to the full awareness of the operator. In other words, the interface must be optimized for the most effective use by the operator. Also, information derived from sensors on the slave manipulator must be enhanced by the interface software in order to make it as useful as possible to the operator. Since the human's instincts are to operate in real-time, the sampling rate of the system must exceed 30 hz. The manual controller is effectively a light weight robot which drives the slave manipulator through digital commands. Hence, this system is essentially equivalent to two cooperating robots. This is why numerical interfacing of a manual controller and a robot manipulator is much more difficult than operating an autonomous robot.

III. CRITERIA FOR ADVANCED ROBOTICS TECHNOLOGY

The following is a listing of 14 distinct criteria that may be used as indicators of the level of the technology available in an advanced robotic system and may be a useful means to judge progress of the technology under development.

1. Multi-task capability means the number of different physical tasks that can be performed by the same robotic system.
2. Level of machine intelligence implies the level of integration of computer hardware, software, and artificial intelligence to make the system as autonomous as possible.
3. Time efficient operation implies the speed at which the robotic system performs its task relative to the human performing the task alone.
4. Unstructured task level suggests the level of numerical uncertainty of the operation that is to be performed by the robotic system.
5. Geometrical dexterity is an indicator of the motion range the end-effector can move through while performing physical tasks.
6. Portability and mobility implies the level of movement the total robotic system has relative to a stationary (fixed shoulder) manipulator.
7. Precision is an indication of the absolute precision of placement of the end-effector in world coordinates in response to simple numerical commands.
8. Load capacity clearly implies the ability of a robot to carry or resist a given load without major deformation.
9. Reliability is an indicator of the failure rate of the total robotic system.
10. Obstacle avoidance suggests the ability of the robot to avoid obstacles in its work environment.
11. Force sensing suggests the measurement of forces in the manipulator system to be evaluated by the machine intelligence to judge working forces or to compensate for manipulator deflections.
12. Smoothness of operation implies the lack of backlash or very large deformations in the manipulator system.
13. Operational envelope gives an indication of the working range available by the robot without moving its shoulder.
14. Vision corresponds to shape recognition either by analog feedback to the human operator or by digitizing the scene and providing numerical shape recognition.

TABLE 5: - ESTIMATE OF LONG TERM IMPORTANCE OF ROBOTIC CHARACTERISTICS FOR VARIOUS APPLICATIONS

Estimate of Importance of Robotic Characteristic for Various Applications Robotic Characteristic	Average	Micro-Processing	Assembly	Light Machining	Welding	Riveting	Fission Reactors	Fusion Reactors	Oil Production	Coal Production	Fuel Handling	Ocean Operations	Battlefield Op.	Emergency Repair	Ammunition Hdlg.	Strategy Develop.	Micro-Surgery	Prosthetics	Agriculture	Accident Missions	Service Robots
1. Multiple Task Capability (2)	6.3	4	5	3	8	4	10	10	10	5	5	8	8	7	3	5	8	4	4	8	7
2. Level of Machine Intelligence (1)	7.1	5	7	8	8	10	7	7	7	3	5	9	9	6	5	10	7	4	4	6	5
3. Time Efficient Op. (6)	5.4	6	6	4	5	5	7	7	6	3	3	7	6	5	6	7	6	3	8	5	3
4. Unstructured Task Level (7)	5.2	2	2	2	7	4	7	7	7	4	3	7	7	7	2	7	7	4	4	10	5
5. Geometric Dexterity (10)	4.8	4	6	4	7	3	7	7	7	4	3	7	6	5	4	-	7	3	4	6	3
6. Portability & Mobility (4)	6.1	2	2	2	6	6	7	7	10	10	5	10	8	6	4	-	3	8	8	10	8
7. Precision (5)	5.5	10	7	10	7	7	5	6	6	5	4	5	5	6	6	-	10	3	3	3	3
8. Load Capacity (12)	4.7	1	3	10	7	7	5	7	6	6	4	5	5	4	8	-	2	3	4	4	3
9. Reliability (3)	6.3	5	5	7	5	5	5	6	7	6	8	7	7	5	8	7	6	7	7	8	5
10. Obstacle Avoidance (8)	5.1	4	10	5	8	3	4	4	4	5	5	7	5	5	7	-	4	3	5	7	7
11. Force Sensing (11)	4.8	7	7	10	6	6	3	4	4	4	4	5	5	5	3	-	10	4	3	3	3
12. Smoothness of Operation (13)	3.8	7	5	10	5	3	2	2	2	2	2	3	3	3	3	-	10	5	3	3	3
13. Operational Envelope (14)	3.1	4	7	3	6	5	2	3	2	3	2	2	2	2	4	-	4	3	3	3	3
14. Vision (9)	5.0	10	10	3	8	7	2	3	2	4	5	7	6	5	2	-	8	2	8	4	4

TABLE 6: IMPORTANCE OF ROBOTIC CHARACTERISTICS BY APPLICATION GROUPS

Robotic Characteristics	Average for all Applications	Industrial Automation	Energy Systems	Military Operations	Human Augmentation and Agriculture
1. Multiple Task Capability	6.3	4.8	8.0	6.2	6.2
2. Level of Machine Intelligence	7.1	7.6	5.8	7.8	5.2
3. Time Efficient Operation	5.4	5.2	5.2	6.2	5.0
4. Unstructured Task Level	5.2	3.4	5.6	6.0	6.0
5. Geometric Dexterity	4.8	4.8	5.6	5.5	4.6
6. Portability and Mobility	6.1	3.6	6.8	7.0	7.4
7. Precision	5.5	8.2	5.2	5.5	4.4
8. Load Capacity	4.7	5.6	5.6	5.5	3.2
9. Reliability	6.3	5.4	6.4	6.8	6.6
10. Obstacle Avoidance	5.1	6.0	4.4	6.0	5.2
11. Force Sensing	4.8	6.2	3.8	4.5	4.6
12. Smoothness of Operation	3.8	6.0	2.0	3.0	4.8
13. Operational Envelope	3.1	5.0	2.4	2.5	3.2
14. Vision	5.0	6.6	3.2	5.0	5.2

For all applications, the most important robotic characteristic does not outrank the least by more than a factor of two. The range is up to a factor of 4 among some of the application groups. This data is partially tabulated below in order to establish the most siginificant properties of robotic systems for each application group. Generally, as the application warrants or allows autonomous operation, the characteristics of machine intelligence, precision, vision, sensing, and reliability become important. For unstructured task applications requiring a balance between man and machine, characteristics such as multiple task capability, mobility and portability, obstacle avoidance, reliability and unstructured task level have an increased importance.

	Component	Rank
All Group Applications	Level of machine intelligence	10.0
	Multiple task capability	9.0
	Reliability	9.0
	Mobility and portability	8.6
	Precision	7.8
	Time efficient operation	7.6
Industrial Automation	Precision	10.0
	Level of machine intelligence	9.3
	Vision	8.3
	Force sensing	7.5
	Smoothness of operation	7.3
	Obstacle avoidance	7.3
Energy Systems	Multiple task capability	10.0
	Portability and mobility	8.5
	Reliability	8.0
	Level of machine intelligence	7.2
	Load capacity	7.0
	Geometric dexterity	7.0
	Unstructured task level	7.0
	Time efficient operation	6.5
	Precision	6.5
Military Operations	Level of machine intelligence	10.0
	Portability and mobility	8.9
	Reliability	8.7
	Time efficient operation	7.9
	Multiple task capability	7.9
	Obstacle avoidance	7.7
	Unstructured task level	7.7
Human Augmentation & Agriculture	Portability and mobility	10.0
	Reliability	8.9
	Multiple task capability	8.4
	Unstructured task level	8.0
	Vision	7.0
	Obstacle avoidance	7.0
	Level of machine intelligence	7.0

One of the principal responsibilities of a research team is to develop the technological criteria necessary to measure the impact of proposed or actual advances in that technology. For robotics, as an immature field, many of the criteria are new and relatively unknown in their overall importance to the resulting system's operation. The following 14 factors should prove adequate to define and evaluate a generic robotics technology.

1. Multi-Task Capability

The operational task spectrum of most industrial robots is severely limited. Some are limited to a single function such as pick-and-place. Others can perform sequential spot welds or pre-programmed painting. The most advanced system of this type can perform approximately 20 distinct operational functions.

The concept of multi-task capability means that a wide range of functional tasks can be performed by the same robotic system. This concept can be illustrated by the example of PWR steam generator maintenance where the sleeving task may require up to 25 sequential sub-tasks all representing distinct operational requirements. The steam generator presently requires 18 tasks such as plugging, sleeving, etc. The nuclear steam system of PWR's represents 10 distinct system component tasks such as the steam generator, pumps, valves, etc. The combined generality of system tasks, component tasks, and sub-tasks is the primary reason why a generic technology is essential for a multi-purpose robotic system operating within an unstructured environment. Should the unstructured nature of the task be articulated by unknown or unfriendly forces, the need for generic technology becomes even more critical.

2. Level of Machine Intelligence

The primary objective of machine intelligence is to produce a quality of motion at least equivalent to the human acting alone. To accomplish this level of performance requires a level of sensibility to the operational environment and supporting intelligence similar to the sensing and reflex action (distributed intelligence) in the human arm. Since no robotic system today exhibits any significant level of intelligence, effective integration of machine intelligence would provide a real opportunity for improved performance. Simple off-line pre-programming is insufficient to treat the unstructured task spectrum described in item 4 below. A combination of human intelligence and machine intelligence in a balance best suited to perform a given range of tasks is recommended for the performance of all but the simplest structured tasks.

3. Time Efficient Operation

In many robotic functions, the time required to perform a given task may have significant economic impact or it may be crucial to the overall effectiveness of the task being performed.

For nuclear reactor maintenance, the availability of the reactor for power production is a major economic issue. In military operations, time may be essential in response to a surprise attack or a rapid change in tactical plans. The essential requirement is that the robotic system be at least man-equivalent in this regard. In nuclear reactor maintenance, the goal should be to reduce task times by 50% which would have hundreds of millions of dollars per year benefit. The present light duty hot-cell master/slave systems exhibit task performance eight times slower than the human acting alone. However, if the human operator is removed completely from the hazardous environment, other benefits accrue since the environment can be greatly simplified (reduced cost) or more rapid start-up can be achieved. For this reason, an improvement of two or three times in direct task time performance (over the present technology) by the robotic system may well prove sufficient to achieve overall task times one-half of those for the human acting alone.

4. Unstructured Tasks Level

Here the concept of an unstructured task means that the operational environment is not quantitatively known to the operator, to the machine intelligence, or to the data base. Many systems such as nuclear reactors are documented as designed not "as built" and they frequently are not provided with any reference benchmarks. This means that sensing feedback (both force and visual) is essential to the performance of unstructured tasks. Machine intelligence enhances this perception and makes system performance more accurate and rapid. Generally, most existing systems for remote operations provide a modest capability to treat the lack of definition represented by the unstructured task.

5. Geometrical Dexterity

Geometrical dexterity is meant here to denote end effector motion of great generality in space. The human hand moves with a first level of dexterity augmented by the additional 6 DOF supplied by the human shoulder. Using a fixed shoulder would dramatically limit the human arm's dexterity. The ability to analyze arm geometry is now well established. To design for a required level of dexterity has been shown to be feasible and progress is being made. One of the best ways to increase dexterity is to add 2 DOF to make an 8 DOF arm. These extra (redundant) DOF makes obstacle avoidance much more likely. Unfortunately, these redundant DOF make the control of such an arm very difficult. A solution to the dexterity design problem is required in order to provide the designer an essential tool to select the best possible manipulator geometry.

6. Portability and Mobility

Portability of the robotic system implies that it can be broken down into modules which can be carried to the work place by a human operator and quickly assembled. The suggested weight limit per module is 35 lbs. Such a weight restriction creates an unusual demand to design light weight actuators and to use special light weight materials (composites or carbon fiber).

Mobility implies that the system could move over (or traverse) an obstacle strewn area. To date, no such system exists in the general sense. Special tracked vehicles, track followers, and wheeled vehicles are used to traverse relatively smooth surfaces (or fixed tracks) with minimal obstacles. Unfortunately, for many applications, these special conditions do not exist. Mobility would have special significance to surveillance and to dedicated autonomous units for military applications, accident missions, and ocean floor activity. During the past 20 years, significant laboratory work has been on-going on the generic concept of walking machines for mobility purposes.

7. Precision

The absolute precision of most industrial robots is known to be not better than 0.05 inch and many are far less accurate. Yet, many assembly, welding, and light machining operations require a precision of 0.01 inch. Further, fine positioning to 0.001 inch is sometimes necessary. For the example of nuclear reactor maintenance, the overall need, with regard to precision, is equivalent to that of a portable machine shop. This level of precision puts an unusually demanding resolution requirement on the actuators and their control system. The control encoders and actuators must be capable of steps of 10 seconds of angular rotation. Most actuators fall far short of this, especially if they must provide a high load capacity. In addition to these precision requirements, the more difficult condition is to maintain precision while the manipulator experiences large load variations. It is common for external loads to degrade the unloaded precision by a factor of ten. The reader can prove this reality to himself by "shaking hands" with a few industrial robots. It is not uncommon to easily achieve oscillations of 1/4 inch in magnitude.

8. Load Capacity

The load capacity of the arm is primarily dependent on the size of the arm's actuators. Generally, about 90% of the arm's deformation occurs at the actuators. Today light duty arms are designed to carry 10 lbs. Infrequently, arms are designed to carry 200 lbs. but they are heavy, imprecise, sluggish, and certainly not portable. A load capacity of 200 lbs. is recommended for stream generator maintenance in nuclear reactors. In micro-surgery, load capacity may be measured in ounces. One of the best ways to improve load capacity is to place the actuators in a parallel structure so that they can be carried by the base and not by the arm as they are presently for serial manipulators. Another useful effort is to seek an optimal distribution of actuator sizes in a given arm geometry.

9. Reliability

Industrial robots, today, have established a very high operating availability of approximately 98%. These units are marketed only after prolonged testing and redesign. Nonetheless, in other unique applications, this extensive history is not available to ensure high realiability. This property is especially important in such operations as nuclear reactor maintenance. Failure would mean difficult retrieval and an extended down time (at great cost) of the power plant. Here, the goal is failure in 1 of 20 field operations (each lasting 2 to 5 days). Failure is also unacceptable where human life is involved as in accident missions, military operations or ocean floor activity. Predictably, the simpler systems having lower intelligence will be substantially more reliable. Hence, it can be recommended that for an integrated system with all technologies implemented, numerous field demonstrations will be necessary to perfect the system in order to make it sufficiently reliable.

10. Obstacle Avoidance

Many unstructured tasks must be performed within a volume containing known, unknown, or moving obstacles. Today, working in an obstacle strewn environment is rarely considered in automation operations on the factory floor. Almost no existing robot has a significant level of obstacle avoidance capability although those which are anthropomorphic are more able to avoid obstacles. In the case of steam generator maintenance, access is difficult. In nuclear reactor systems, the maintenance operation for piping and valves is heavily obstructed by obstacles. The best way to achieve increased avoidance capability is to increase the generality of the arm's geometry. Beyond this, increasing the DOF to 8 will prove very beneficial. Unfortunately, both of these steps make the design and control problems much more difficult. Having the increased generality makes increased machine intelligence essential to benefit from proximity sensors on the arm.

11. Force Sensing

Force sensing is the most basic sensing parameter necessary for feedback to the operator or to the machine intelligence of a robot operating in an unstructured task regime. Other sensors are tactile sensors in the fingers of the end-effector, torque sensors at the actuators, etc. An accurate level of sensing should dramatically improve the system's operation making it possible to perform such functions as hammering which are essentially impossible today. Assembly operations are known to be significantly faster and more reliable with force sensing in the system. Some servo master/slaves exhibit a reasonable level of force sensing today. Unfortunately, the master/slave system can not easily be generalized and does not lend itself easily to the integration of machine intelligence.

12. Smoothness of Operation

Smoothness of operation of the system implies that no unexpected or unpredictable phenomena disturb the human operator or the machine intelligence in the performance of the operation task. These disturbing phenomena are backlash and large system deformations. Present light duty arms avoid backlash but they exhibit very high deformation under load. Present heavy duty arms may allow as much as 1/4 inch backlash at the end-effector. Advanced system design must avoid these pitfalls.

13. Operational Envelope

The reach of the arm directly affects the size of the operational envelope or field of movement of the manipulator arm. Small arms (of 3 ft. reach) tend not to be able to duplicate the scale of human motions. Many maintenance tasks for nuclear reactors and some military applications require arms of 6 ft. in length. Unfortunately, the stiffness of these arms is inversely proportional to the cube of its length; i.e., it becomes compliant very rapidly. But the reach concept of the arm is much more involved than it first appears. To be able to approach an extreme position and remain dexterous is usually not possible. As one approaches the limits of the operational volume, dexterity deteriorates rapidly. Maintenance tasks such as steam generator sleeving require high dexterity throughout the work volume.

14. Vision

The sensing information by analog or computational vision is known to be an essential ingredient in the operation of robotic systems in unstructured task regimes. This information may go directly to the human operator or to the machine intelligence, or to both. Recent progress in analog vision has been sluggish and no breakthroughs are expected. Analog vision displayed for the human operator enhanced by machine intelligence is an untapped opportunity. Furthermore, the use of digital vision or graphics could be valuable in training systems for the location of obstacles and other features. Vision technology can be enhanced by better integration of automatic camera control and foveal vision.

Mr. WALGREN. Thank you very much. We appreciate that, Dr. Tesar. I suppose it is not an uncommon comment that on the congressional level things are relatively poorly defined, so that is probably not an unusual state of affairs. We appreciate your testimony, and particularly the detail. In view of the significance of the presentation, I didn't want to limit it in time but I will restrain myself in questions because we have gone that long.

But let me recognize my colleagues on the committee for points they would like to raise. The gentlemen from New York, Mr. Lundine.

Mr. LUNDINE. Thank you, Mr. Chairman.

The first question that I have is, do we have those charts? I feel like an old sponge. There has been a whole lot of material there, and I'm not sure how much I have absorbed. Are they in here?

Dr. TESAR. Yes, sir, in about the middle of the testimony that is written.

Mr. LUNDINE. All of them that you used?

Dr. TESAR. Well, not all of it but a good share of important charts are included.

Mr. LUNDINE. I saw that some charts were here but they didn't seem to be the same ones that you were using in your presentation.

Dr. TESAR. I see.

Mr. LUNDINE. Mr. Chairman, if there is any way that our staff can subsequently get us——

Mr. WALGREN. Perhaps you could review your video slides and correlate it with your testimony. If there is something that you don't have in the testimony, we would appreciate having it for inclusion in the record.

Dr. TESAR. Yes, sir.

Mr. LUNDINE. Thank you very much, because they were really excellent and I could barely grasp——

Dr. TESAR. I appreciate that.

Mr. LUNDINE. Dr. Tesar, the most common criticism of all of these bills is that surely no bureaucrat can pick successful technology, only the marketplace can do so. What would be your comment?

Dr. TESAR. There's all kinds of marketplaces. One is the human capital marketplace, and the universities are a wonderful environment for the human capital marketplace, so if you put these centers near the universities where there is mutual benefit, and negotiate an interaction between them—the customer which is industry and the producer which is the university—you have enhanced that market definition, not diminished it.

Mr. LUNDINE. You mentioned that the amount in one of the bills—$3 million for a center and having 10 centers around the United States—was inadequate. Wouldn't you consider the possibility that industry and the university itself, other private investor sources, might provide additional funding?

Dr. TESAR. Yes, sir. I think that's completely feasible and with a certain amount of base funding, as suggested in these bills, that's very likely. We have, for example, one of the next testimonies is from Carnegie-Mellon, and they have been very successful in this regard.

On the other hand, the norm is 3 percent in the United States, direct support from industry to the universities, and that is just not sufficient to have mutual benefit, negotiated interactions, and subcontracts.

Mr. **Lundine**. So even considering the possibility of the private sector contributing or even contracting for some research, you feel that the $3 million is inadequate.

Dr. **Tesar**. If you restrict yourself to the field of robotics and the use of robotics for manufacturing, I am not overly concerned about the number. I think it's in the ball park. I am very concerned, however, about the much broader scale view of manufacturing in the bill H.R. 4415 and the magnitude of that is not sufficient relative to what we mean by "manufacturing."

Mr. **Lundine**. Then by no means were you suggesting that robotics is the only area to concentrate on. For example, aren't there advanced developments in metallurgy that could completely change the composition of materials that we might be using in manufacturing?

Dr. **Tesar**. Certainly. It's a very valid point. May I mention that 40 percent of all the basic research in the United States is spent in materials research in engineering, so there is a tremendous commitment to materials already in the United States. However, to manufacture those materials and transform them, as the Japanese do, for value added into a market product that can be sold, where precision and quality and response to the market and reduced inventories are the issues, we don't have very much funding in the United States.

Mr. **Lundine**. Thank you very much, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Lundine.

Mr. MacKay?

Mr. **MacKay**. Good to see you here.

Dr. **Tesar**. Thank you.

Mr. **MacKay**. You have made a number of points, and I would like to zero in on the point where you talk about national policy for manufacturing. I find it on page 16.

Dr. **Tesar**. Yes, sir.

Mr. **MacKay**. You say during the last decade the United States has lost 30 to 50 percent of its take-home pay per worker relative to other developed societies such as Japan and Northern Europe, and you say since our markets are open to all competition, some of it unfair, our only protection is to run faster than our competition, and you think we need to have a national policy. Now that is one of the fundamental controversies up here.

Dr. **Tesar**. That's right.

Mr. **MacKay**. There is a great hesitation to get into a situation where Government is trying to do the planning. I would like your comments on that. Do we have a national policy now? Also, the next section, the relative role of high-tech and low-tech, what should we be doing in the manufacturing area that we're not doing? What should we be doing to support the steel industry and our basic industries?

Dr. **Tesar**. Fair enough. Well, first of all, I do believe and sincerely that the United States is losing its ability to compete in manufacturing, which is the primary business of creating wealth. If you look over the last decade, you will see a loss of 30 to 50 percent of your relative take-home pay per worker in the United States, and we have a very heterogeneous society. We have to be much more knowledgeable about our manufacturing base than we have been in the past, and the only way you can be long-term knowledgeable and commit yourself to human capital is to have distributed, interactive discussions among the market drivers—which are your industrial customer—and the university that produces the long lead-time research, let's say, and also the human capital. So my reaction to the dilemma that we face is that we ought to get started somewhere—right?—and the universities, it seems to me, are the best neutral ground. We have 250 engineering schools around the United States, and let's say 50 of these became actively involved in this question. The distributive question would take care of itself to a great extent and the centralized planning would be much less visible.

We need, however, initiative to get something like this started, to get visibility and get excitement, enthusiasm, and I don't see enough initiative at the Federal level to match that initiative you might see, let's say, in Japan, Sweden, Germany, France, and also—if I might say so—in Russia.

Mr. **MacKay**. So what you are saying is, there is a way to better focus without having government planning per se.

Dr. **Tesar**. That's my perception, yes.

Mr. **MacKay**. To put into place a process so that the people who are out in the trenches, which is our industry groups, would be more interactive with the people who are back taking a longer term view. Is that right?

Dr. **Tesar**. Exactly, and if we can get that started, you then build up the advocacy in response to the market pressures from the customer, and advocacy is one of the best things that you can have, if it is distributed, to affect national policy. I am suggesting that if you have only 6 percent of your Nation's scientific manpower associated with manufacturing in the civil sector, you don't have enough advocacy to change the base of decisionmaking.

Mr. **MacKay**. You at one time had a set of charts—like you, I am fascinated by the charts—that showed or seemed to show a correlation between where we had put tremendous amounts of Federal R&D money——

Dr. **Tesar**. Yes.

Mr. **MacKay** [continuing]. For instance, aeronautics, and market share, and also seemed to show that there was almost like an inverse correlation. The more American jobs that were involved, the less Government money had been involved in R&D—for instance, manufacturing.

Dr. **Tesar**. I would have to agree with all those comments. That seems to be essentially the case. In other words, where most of our jobs are, we have the least industrial policy to protect them in this country.

Mr. **MacKay**. And the least Federal effort.

Dr. **Tesar**. That's right. I would have to agree with that.

Mr. **MacKay**. The last thing: We have spent a great deal of time looking at the issue of how you get new ideas from the basic R&D stage to the commercial stage, commercialization of R&D. It appears that although we may be doing a better job in basic research than the other, competing nations, they do a much better job at commercializing the new ideas.

Dr. **Tesar**. Yes.

Mr. **MacKay**. Were you saying in your comments today that the key to that should be the National Bureau of Standards?

Dr. **Tesar**. I think that the National Bureau of Standards has a vital role, and that is to demonstrate the need in sharp detail, on a consistent, long-term basis, repetitively looking at these issues over and over again, monitoring what's happening to us internationally.

For example, about 3 years ago I asked the question: What is the distribution at the micro level of the technologies in engineering among, let's say, the most important 10 manufacturing countries in the world? I couldn't find it anywhere in our depository of information in the United States, the National Science Foundation, NBS, OTA, wherever. I could not find that comparative analysis, and the most long-term commitment any society has is to its distribution of manpower. Therefore, if you want to find out what the Russians are doing, find out how they are spending their money for their manpower today; you will see what they will be doing 15 or 20 years from now.

If we could find out comparative analysis like this through, as I say, a long term commitment through the National Bureau of Standards, you would have a much better chance of making decisions where you sit.

Mr. **Lundine**. Would the gentleman yield?

You probably could find that out for Japan, couldn't you?

Dr. **Tesar**. I think in that case, but it wouldn't be comparative in a sense. In other words, I could find out, but I would have my own biases. We need somebody in a neutral environment like NBS to make the statement in an analytic sense and make it comparative among enough countries so that it has real meaning.

Mr. **MacKay**. If I might, Mr. Chairman, let me explore that just a little further. I have heard the issue of R&D and where we're headed in the future described in a fashion that said the manpower shortage in the key spots in technology transfer and R&D is going to be the controlling factor. Not dollars, but the manpower, trained, skilled, innovative manpower will control. Would it be fair to say that, although Government might not get involved in planning by, for instance, subsidizing one industry or subsidizing technology in one area, that Government might get involved in at least trying to plan where the manpower needs are going to need to be 20 or 30 years from now and being sure we are subsidizing the training of skilled manpower?

Dr. **Tesar**. I would say that if we had accurate information on what is happening to us internationally on the manpower basis, that would take care of much of the planning almost naturally. We don't have accurate information, so we have an anecdotal response or we have a lot of hearsay evidence; that's not sufficient to make policy, so I am very concerned about it. But I would say this, that yes, manpower is very important but you can overproduce manpower.

When I was in India, for example, I saw in almost every newspaper I picked up, complaints by engineering students that there were no jobs, so if you don't have a policy that absorbs these people, you can overproduce people in a hurry. It has to be a uniform, cohesive, integrated plan that moves the whole thing forward uniformly.

Mr. **MacKay**. Well, the Federal impact thus far has been very counterproductive.

Dr. **Tesar**. Oh, yes. I would have to say in many ways that is true. If you want rapid response, you have to have manpower in the wings, so if you don't have the manpower in existence you can't respond as rapidly.

Mr. **MacKay**. On the other hand, the Federal Government in the sixties probably overstimulated the university system to produce engineers and other scientists far in excess of our needs which led to a great deal of frustration in the seventies, which probably has led directly to the shortages in the eighties.

Dr. **Tesar**. Well, I think there's a lot of agreement on my part on that. I would have to say that never were more than 1.6 percent of the engineers out of work. In addition, I would have to say that there were movements from one technology base to another technology base which created a lot of concern by individuals, and these were expressed. I would be reluctant to say that we had too many engineers. I wouldn't say for sure that we had too many.

Mr. **MacKay**. What I guess I am asking you is, how would you take that concept and transfer it into reality? What you're saying is, somebody ought to do better long-term planning in terms of manpower training.

Dr. **Tesar**. That would be one of the first things to do.

Mr. **MacKay**. But that has typically been a responsibility of State government.

Dr. **Tesar**. Yes. As a matter of fact, I think that's true. The competition among the States creates a response in manpower.

Mr. **MacKay**. The question is whether they've got a broad enough world view in terms of 10 or 20 or 30 years, to make the decisions about——

Dr. **Tesar**. It would be less likely that they would.

Mr. **MacKay**. Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. MacKay.

Let me ask you, Dr. Tesar, on that point that Buddy has raised on take-home pay, you indicate that we have lost 30 to 50 percent relative to northern Europe and that that number should be verified. What's the short description of how that number is arrived at, and can you direct our staff towards any materials that they could use to look at that number?

Dr. **Tesar**. I think it's the CED that puts out documentation of this type, which has documented that, and there has been analysis of that but I cannot go back to the original source. That's one of my discomforts with that statement, as a matter of fact, that I could not go back to the original analysis. It wasn't sufficiently well documented so I couldn't find out who actually made the analysis, and that's why I say it should be carefully verified. It is uniformly accepted that that is true, however.

Mr. **Walgren**. Well, we would like and perhaps we will be in touch with you on developing that number.

Now you indicate that the heavy machinery is relatively properly supported in an investment sense in this country but the light machinery is not. What two primary reasons would you give for our failure to support the light machinery in the same way that we apparently do heavy machinery?

Dr. **Tesar**. That's a very interesting question. Since I am a university faculty member, I have thought about that some. I teach machine design at the University of Florida, for example, and in that area I have the responsibility to define curriculum or what have you. The primary emphasis we have in our curriculum has to do with the failure of machines—that is, the life of the machine, how long does it last; reliability; stability problems for control; that sort of thing. This has a lot to do with the investment in the farm machinery, it has a lot to do with investment in heavy machinery for turbines. It has a lot to do with investment for big machines like presses and that sort of thing.

On the other hand, light machinery requires a concern for precision. When you turn that machine on, the product that that machine produces is the reason for the existence of that machine, and if the product is not of sufficient quality you cannot market that product. We do not teach that, so I would say the universities are to a great extent to blame for our lack of efficacy and priorities in the field of light machinery.

On the other hand, I would have to say also that our laissez-faire approach to this technology has not created enough excitement on the industrial side to become more aggressive in its manufacture. So, for example, in the field of textile machinery we used to have about 50 percent of the world's market in textile machinery in the early fifties, and I believe it's down to at least 8 percent or worse today. In the field of machine tools, which is a precision technology in its ultimate form, we now have only 17 percent of the world's market where we used to have about 30 to 32 percent. So again, you know, in all these areas we are beginning to show tremendous failure in the competition in the field of precision technologies.

Mr. **Walgren**. But really aren't we up against political attitudes as opposed to excitement or, particularly in the universities, the community being able to drive the society?

Dr. **Tesar**. Yes, yes.

Mr. **Walgren**. We are really up against political interests which somehow or other drove the investment in the heavy machinery area and really as consciously, in terms of a self-interest standpoint, prevented an action or a program being undertaken in——

Dr. **Tesar**. I have to agree with that. There are strong political forces, but to build up an advocacy to correct that, it means you have to deal with the manpower, and manpower responds to enthusiasm and excitement. That's what young people respond to. It's the flag that you put on your flagpole.

Mr. **Walgren**. You know, one of the ideas that you raised that really is intriguing from a political standpoint is this idea of different markets. If we can agree that we should be driven by a marketplace, then the question is how do you define that marketplace, and what Dr. Tesar suggests is there might be some smaller sections of our marketplace that, if properly focused on, could be allowed to drive the activity in that area but would give us a different result than if we define as the marketplace my desire for a plastic water squirt gun for my kid and directing my dollars in that direction, as opposed to something that might be more constructive.

Dr. TESAR. Thank you.

Mr. WALGREN. Well, we certainly appreciate your testimony, and I apologize about the time but it was worth it.

Dr. TESAR. Thank you very much.

Mr. WALGREN. The next witness is a constituent of mine, not that that's why he is here. I was surprised to meet him yesterday as I never have before, but we do want to welcome Dr. Frank Pittman, the acting associate director of the Robotics Institute at Carnegie-Mellon University, Pittsburgh, PA. We certainly welcome you, Dr. Pittman, and want to hear your views as fully as you would like to expound them. The written statements will be made part of the record, and feel free to outline points you would like to make in any way that you feel most effective. We are glad you're here.

STATEMENT OF DR. G. FRANK PITTMAN, ACTING ASSOCIATE DIRECTOR, ROBOTICS INSTITUTE, CARNEGIE-MELLON UNIVERSITY, PITTSBURGH, PA

Dr. PITTMAN. Thank you, Mr. Chairman.

Mr. Chairman and members of the subcommittee, on behalf of Carnegie-Mellon University and the Robotics Institute, I am very pleased to have the opportunity today to present this statement to the Subcommittee on Science, Research and Technology. I shan't present the amount of detail that Dr. Tesar did. He gave a great deal of the background for me, fortunately. What I would like to do is to emphasize several of the points that are made in the written statement and to particularly show how they relate to some of the concepts in the bills that are being considered today.

Certainly, without belaboring the point, it certainly does seem very evident that the U.S. manufacturing economy today is being faced with new kinds of competition, people employing new kinds of competitive weapons and, perhaps most significantly, new technologies. Fundamental economics would suggest that what we need to do would be to identify a potential comparative advantage and to exploit that, so the question becomes, what sort of weapon of this kind might be employed.

At the present time the United States does enjoy a leading position, albeit perhaps a tenuous one, in advanced computer science. Here then, perhaps, lies a potential comparative advantage—to infuse capital into the U.S. manufacturing economy in the form of computer technology, in other words, intelligent robotics, thereby enhancing the productivity of the work force, maintaining our global competitiveness, and also supporting our standard of living. That's easy to say but perhaps not so easy to do.

We believe, and this certainly is reflected in the bills that are under consideration, that pursuing this end absolutely requires some cooperative effort, more cooperative effort, among academia, industry, and Government. Our lead in advanced computer technology must be maintained and even increased. Also, we must take action to facilitate more efficient and more effective technology transfer between the universities, where much of this technology resides, and industry where it must be utilized and implemented. The bills under consideration certainly do address these points, we feel.

In many ways, the experience that we have had at the Carnegie-Mellon University Robotics Institute over about the last 5 years can be viewed perhaps as a prototype of some of the industrial, academic, and governmental cooperation of the sort that is being considered, and for that reason I would like to say just a little bit about that. The Robotics Institute was conceived out of thinking that is not unlike that that lies behind these bills, particularly on the part of Dr. Richard Cyert, the president of Carnegie-Mellon University, and Mr. Thomas Murrin, who is the president of one of the major segments of the Westinghouse Electric Corp.

The institute was founded in late 1979 with Westinghouse as the initial sponsor. Somewhat later the Digital Equipment Corp. came on board as another major sponsor. In the years since then, the sponsorship has broadened to include about 25 to 28 industrial affiliates providing an annual research budget of about $8 million. The research program is carried out by over 100 faculty members, research scientists and engineers, graduate students, and supporting personnel. The technical range covers the full scope of physical processes and information processing which takes place within the manufacturing environment. In other words, we use a very broad definition of robotics.

We place heavy emphasis on acquiring, processing, and interpreting information, and then acting upon those interpretations. Development and application of artificial intelligence techniques to manufacturing problems is a major research effort. The stated mission of the Robotics Institute is to carry out research in this broadly defined field of robotics, and also to facilitate the transfer of the resulting technology to industry. Indications to date are that we have achieved some degree of success on both scores.

There are several points, based on our experience, that I would like to cover very briefly. First, the involvement of industrial sponsors is a key item, involvement not only as a source of funds but also as an active participant, both in the planning and the carrying out of the research projects. This is very important to facilitate the transfer of results to industry and their implementation in actual manufacturing operations.

Second, the involvement of academic faculty and students in the programs is also a key element. As was pointed out in some of the discussion earlier, the key element in the future health of the U.S. manufacturing economy is a supply of technically trained personnel. Because of the participation of the academic faculty and graduate students in the research, the institute's activities not only produce research results but also reinforce the educational mission of the university, and this is important.

Third, on the matter of funding, in order to maintain a high quality, effective center of research, a degree of program stability over a number of years must exist. The nature of business, however, is such that long-term commitments are difficult for industry to make. Furthermore, we find—not surprisingly—that industrial sponsors are much more strongly interested in the more applied kinds of research. It's necessary, to carry on an ongoing, effective center, to maintain a balance between applied and fundamental research. We find that in order to do this we must augment the industrial funding with governmental funding to provide some of the more fundamental work.

So these are the key items: We believe that there certainly is a problem. We believe a key element in the solution to the problem is computer science and robotics. We believe that academic institutions, together with Government and industry in a cooperative effort, must play a key role. We strongly believe that the U.S. manufacturing economy is indeed in perilous times and that a vigorous infusion of new technology is necessary to restore and to maintain its vigor. Computer technology is a key ingredient and one in which we enjoy a leading position at present. Maintaining that lead and effectively transferring the technology to industry will require the kind of cooperative efforts among Government, academia, and industry that are being discussed here today.

Thank you very much.

[The prepared statement of Dr. Pittman follows:]

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Statement for the Subcommittee on Science, Research and Technology
Hearings on Federal Organization for Technological Innovation

Dr. G. Frank Pittman
Acting Associate Director
Robotics Institute
Carnegie-Mellon University
June 13, 1984

On behalf of the Carnegie-Mellon University Robotics Institute, I am pleased to have this opportunity to present testimony to the Subcommittee on Science, Research and Technology.

The two bills under consideration at this hearing are based on the premise that the manufacturing economy of the United States in its traditional form is threatened by a new kind of global competition. Indeed traditional geographic patterns of manufacturing, marketing and distribution have been shattered. United States manufacturers are faced with new competitors employing new kinds of competition and, perhaps most significantly new technology. Initially at least, the United States appears to be doing poorly in this new competitive environment. It seems evident that something must be done to restore and maintain the competitive position of our manufacturing industries.

Fundamental economics would suggest that we need to identify a potential comparative advantage and to exploit it. The question is - what sort of comparative advantage might that be.

The United States worker owes his superior standard of living to the heavy capital investment of our manufacturing economy which has made it the most productive in the world. To continue to improve or even to maintain this standard of living in the face of increasing competition from countries in which workers enjoy a much lower standard will require further capital investment in support of the United States worker. Looking back in history the first investments by manufacturing industries were made to augment the manual capabilities of workers. Later investments emphasized mass production systems to efficiently produce large quantities of standardized products at low costs. We now have the opportunity to invest in technology to augment the more intellectual, knowledge intensive functions performed by workers.

At the present time the United States enjoys a leading position- albeit a tenuous one - in computer science. Here then lies a potential comparative advantage: to infuse capital into United States manufacturing in the form of computer technology, thereby enhancing the productivity of the work force and maintaining the global competiveness necessary to support our standard of living.

Accomplishing this end effectively and rapidly will require cooperation among academia, industry and government in a number of areas. The United States lead in advanced computer science must be maintained and even increased. In addition, action must be taken to facilitate efficient and expeditious technology transfer through a tighter coupling between the universities where much of the advanced computer know-how resides and the manufacturing industries in which it is to be employed. The two bills under consideration at this hearing address these areas.

In many ways the experience gained at the Carnegie-Mellon University Robotics Institute can be viewed as a prototype of the cooperative effort called for in these bills.

Although the federal government has been the major patron of university research since World War II, Carnegie-Mellon University has been the recipient of a relatively large amount of private funds for research purposes. In 1983 the amount was $18 million, which was over one-third of the total research budget. We believe that this stems in part from an increased appreciation for the value of research on the part of corporate executives, recognizing that the United States could lose its technological lead on the rest of the world. At Carnegie-Mellon, cooperatively sponsored research centers have been established in the areas of magnetics, graphic design and steel production, to name a few.

The Robotics Institute was conceived out of thinking along the same lines that has prompted these bills, particularly on the part of Dr. Richard Cyert, President, and other top officials of Carnegie-Mellon University and Mr. Thomas Murrin and other top executives of the Westinghouse Electric Corporation. The institute was founded in late 1979 under the initial sponsorship of Westinghouse. Somewhat later the Digital Equipment Corporation became a second major sponsor. In the succeeding years the institute has expanded its affiliations to twenty eight sponsors who provide an annual research budget of eight million dollars. The research program is carried out by over 100 faculty members, research scientists and engineers, graduate students and support personnel. The technical range of the Robotics Institute is a broad one embracing the full scope of physical processes and information processing which take place within the manufacturing environment. Heavy emphasis is placed on acquiring, processing, interpreting and acting upon information. The development and application of artificial intelligence techniques to manufacturing operations constitutes a major research effort. The stated mission of the Robotics Institute is to carry out research in the broadly defined area of robotics and to facilitate the transfer of resulting technology to industry. Indications to date are that a degree of success has been obtained on both scores.

There are a number of aspects of the organization and operation of the Robotics Institute which we believe to be significant. I would particularly like to mention several of them.

The Institute seeks to involve industrial sponsors not only as a source of funding but also as an active participant in both the planning and the execution of projects. This approach helps to insure the relevance of the research and to facilitate the transfer of results to industry and their implementation in actual manufacturing operations. The active involvement of industrial personnel in the research projects also enhances and upgrades their skills in advanced technological areas.

A key goal of the Robotics Institute is to promote and assist in the transfer of new technologies to industry. In addition to the direct involvement of industrial personnel, this is further facilitated through the publication of technical reports and an active program of symposia, tutorials and workshops for industrial sponsors.

The future health of the United States manufacturing economy requires a supply of technically trained professionals. Because of the participation of academic faculty and graduate students, the institute's activities also reinforce the educational function of the university and directly result in a supply of graduates with specific training in robotics and an appreciation for industrial problems. The academic faculty also provide an ongoing tie to the traditional academic departments and to the more fundamental research activities of those departments.

The Institute seeks to maintain a balance between applied and fundamental research. We have found, not surprisingly, that industrial sponsors are more strongly interested in the more applied activities and that support for the more fundamental work must often be sought from governmental sources. The bills under consideration would work to maintain this important balance by both encouraging industrial sponsorship and by providing funding for more fundamental research activities.

An increased level of cooperation between universities and corporations in research must overcome two major hurdles. The first one comes from the corporate side in the need to have something tangible to show for its research expenditures when justifying such expenditures to stockholders. This encourages corporations to seek ownership of results of research expenditures in the form of patents. Universities have traditionally covetted the patent rights for any research undertaken in the university. The second obstacle to cooperative research at a university is the need for publication. A major mission of a research university is to develop new knowledge and to make this new knowledge available to other researchers. Quite obviously a change in attitude on both sides is critical if cooperation on research between universities and corporations is to take place. At the Robotics Institute we believe that we have accomplished this with a type of agreement which incorporates flexibility in patent rights and which grants the university the right to publish at an appropriate time.

Maintaining a high quality, effective center of research requires that a degree of program stability exist over a number of years. However, the nature of business is such that long term commitments are difficult for industry to make. The provisions of these bills could provide a base funding level for three or four such centers which would provide them with the required stability and the flexibility to respond to the needs of industry.

In summary, we strongly share the belief that the United States manufacturing economy is in perilous times and that a vigorous infusion of new technology is necessary to restore and maintain its vigor. We believe that computer technology is the key ingredient, and it is one in which the United States presently enjoys a leading position. Maintaining that lead and effectively transferring the technology to industry will require the kind of a cooperative efforts among government, academia and industry that are proposed in these bills.

Mr. WALGREN. Thank you very much, Dr. Pittman.

You indicate that it makes sense to look where we have comparative advantages and to pursue them. Isn't it also true that we are going to have to run like mad in this area? Because in contrast to classic economics where a capacity put into place will be an advantage through time, in this era of reverse engineering and particularly when one of the magical things we are seeking is idea content and the like, as soon as that is published and as soon as one of these foreign competitors can get their hands on the physical product, we find them really beating us to any punch that we are able to put together.

In another committee we had evidence of the Japanese interests literally bribing for the procurement of a new IBM product so they could develop the software for it before we had developed the software for it, so when the product came out on the market they were already there with all the follow-on to satisfy the demand that was created by that product.

Do you think we can run fast enough to yield substantial employment to our society, in view of the transferability of this stuff?

Dr. PITTMAN. It is certainly true, as you point out, that the situation is an extremely dynamic one. That is one of the reasons that it is necessary not only to carry out some research in specific areas and get particular results but also to, in so doing, put in place the structure in terms of people, trained people, capabilities to carry on additional research, that will provide that as an ongoing direction. That is the thing that can permit us to run fast enough to outpace this.

Certainly in the world today information is transferred very rapidly, much more efficiently than it ever has been in the past, and this will continue to take place, so it's not sufficient to simply achieve first order goals. We also we must put in place the capability to continue to pursue and increase our advantage.

Mr. WALGREN. How do you handle, at the Carnegie-Mellon Robotics Institute, the benefit to a proprietary firm like Westinghouse or some of your other industrial sponsors? You indicate that we have in some fashion, and we probably ought to be really looking for what more we should be doing in that area, added governmental strength to some of the research capacities at the university through some of the Federal programs. Yet if that is targeted and focused on a group of industrial sponsors, then there are other people on the outside looking in. Although their tax dollars are providing the base for this, can't they then at least directly participate in the results?

Dr. PITTMAN. That's a key point and it's one of the areas of difficulty in establishing the proper kind of relationship between an industrial sponsor and university research. The industrial sponsor rightly feels that he must show something in return for his contribution. That usually means ownership of patents, proprietary rights to information, and so on. The university, on the other hand, has a requirement in terms of its overall mission to not only create knowledge but to publish and disseminate it, so here we have a conflict of interest really.

We have handled this with some degree of success by establishing a variety of different kinds of relationships, depending upon the specifics of the sponsorship. In the case of a program, a project that is sponsored solely by one sponsor, one industrial sponsor, we have given proprietary rights to the ownership of that information to that sponsor. Clearly in the case where there is multiple sponsorship—a consortium of industry people or some combination of governmental and industrial sponsorship—that cannot be the case. In those situations the university retains the ownership of the results and a variety of kinds of licensing agreements are arrived at with the sponsors.

It's an area that is a difficult one, and it is one of the areas that makes the good kind of cooperation rather difficult to achieve, but it is one that we have found can be accommodated in most cases.

Mr. **Walgren**. And the Federal Government's policy of allowing a university to retain a proprietary right essentially gives you the ability to solve that problem.

Dr. **Pittman**. Yes, it does.

Mr. **Walgren**. I guess if the Government were denying the university rights, then it would make it very difficult to work out the various relationships with private sponsors, private participants.

Dr. **Pittman**. Yes, it would, yes.

Mr. **Walgren**. Mr. Lundine?

Mr. **Lundine**. I think that that basically makes the followup point that I wanted to raise with you. Flexibility of such an institute seems to me to be an essential quality, so that you are able to work out different relationships with the private sector in response to different projects that you might undertake.

Dr. **Pittman**. Yes, it definitely is.

Mr. **Lundine**. Your institute is important, not only to the Pittsburgh area and to the corporate sponsors, but to the whole United States. Are there any other general sorts of recommendations you can make to us that would enhance the kind of partnership you have been able to forge there, particularly with Westinghouse and Digital taking such an active role in the establishment of your institute?

Dr. **Pittman**. Certainly the points that I mentioned are important ones. To have the industrial sponsor involved as more than simply a source of funding, and anything that encourages that sort of involvement would be of help. I can imagine several forms that this might take. Perhaps some sort of incentives to have industrial employees actually be resident, on campus, involved in things, and in a way that would be favorable to the industrial sponsor would be very helpful.

The matter of balance in the program and maintaining this balance between the more fundamental, forward-looking research work and the more applied work, is extremely important. It's a balance that can tip very easily, and the provision for a stable base of funding in the more fundamental areas is an important one. That is difficult to obtain from industry because it requires long-term commitments.

Mr. **Lundine**. And it is in that area that you think that additional Federal programs would be important?

Dr. **Pittman**. Very definitely.

Mr. Lundine. You have looked at these bills. Do you have any assessment of the strengths and weaknesses of the individual proposals?

Dr. Pittman. I would share Dr. Tesar's concern with the number of centers that can be viably maintained with the kind of funding that is being discussed. I certainly can't prove that $3 million is insufficient, but on the one hand it's not a great deal. On the other hand, it's not necessarily true that 10 is the right number of centers, either, but I think that's something that would have to be considered in the implementation of that kind of——

Mr. Lundine. Well, I would be concerned if we had too few centers because we already have a situation where in the Silicon Valley and in the Boston area we have this concentration, and yet there is so much of America that doesn't have the same even venture capital characteristics as these do.

Dr. Pittman. Yes.

Mr. Lundine. In New York State we have tried to set up some advanced technology centers, and even there—I don't know, I couldn't say if it's political or not—but there were so many different corporate interests in so many different areas, ranging from biology to metallurgy, that they had to establish eight or nine, I think. My viewpoint is that that is all to the good because you don't concentrate all of your investment in one place, and the spinoff advantages economically don't all inure to one place.

Would you agree that if we are going to undertake some kind of Federal funding for the development of these technology centers, that it would be desirable to have more than two or three?

Dr. Pittman. I think it would. It would be desirable from several standpoints. First, having more than just a few brings additional points of view, additional resources, additional approaches to bear. However, it would also be important, I believe, to maintain appropriate kinds of communication between the various centers or elements active in the program.

Mr. Lundine. I guess I will conclude by asking sort of a two-part question: Do you think that there is a way that we could establish criteria here that would make the competition for these centers inherently fair, not just providing additional money for those that probably are going to exist anyway, and still not be unfair to existing enterprises such as your own?

Dr. Pittman. Well, it's difficult to say what's fair, I suppose.

Mr. Lundine. Yes.

Dr. Pittman. Certainly great care will have to be exercised in carrying out the process of identifying both the kinds of centers to be encouraged and also the specific location of those centers. It seems to me the criteria that are most important are the ones that relate to the results that are trying to be achieved, more than perhaps the near-term considerations, the results in terms of both well-spent research effort, well-spent research dollars, and also in terms of providing the kind of training for manpower that we feel is so very, very important, so I think the criteria should address those kinds of things: The proposed centers, how well do they fulfill those roles?

Mr. Lundine. Thank you, Mr. Chairman.

Mr. Walgren. Thank you, Mr. Lundine.

Mr. MacKay?

Mr. MacKay. Both you and Dr. Tesar are people who are working at the leading edge of hooking computers together and of robotics. That is a layperson's way of describing what I think you're doing. I think that's very significant. Who, if anyone, do you interface with in the Federal Government now?

Dr. Pittman. We have relationships of a funding nature with the National Science Foundation, and with the Department of Defense. We also are very familiar with and have an interaction with the National Bureau of Standards Program in the manufacturing area.

Mr. MacKay. Do you agree with Dr. Tesar's comment that perhaps NBS could have an expanded role in the whole question of commercialization or technology transfer, being in the role of helping with that part of the R&D pipeline that comes after basic research?

Dr. Pittman. I believe that the role of the National Bureau of Standards in standardization, metrification, and so on is an important one. Certainly the library function that Dr. Tesar mentioned is one that can be effectively carried out there.

In the matter of technology transfer, it has been my experience that the most effective means is direct involvement of the agency to which the transfer is to be accomplished with the agency that is carrying out the research work. I really believe that the primary mechanism could most effectively be the direct involvement of the industrial recipient with the agency that is carrying out the research work. Now whether NBS has a role in that interface is not clear to me. I think they can certainly have an effective role in transfer, in the sense of information dissemination and that sort of thing.

Mr. MacKay. We get a lot of statistics. Our problem is not a lack of information. It's information overload and the inability to take the time and amass the expertise to understand the statistics we're getting. One of the things that is perceived wisdom up here is that a great deal of the innovation in America takes place in small business; a great deal of the job creation, the new thinking, the risk taking. Certainly Westinghouse and Digital are highly innovative companies, but if you because of your funding sources by definition are restricted to dealing with large companies that have got the ability to put this kind of money into it, what does that mean for the whole idea that small business is the generator of innovation. It's almost like we, by our funding sources, are locking out small business from the state of the art. I would like you comments.

Dr. Pittman. Yes. Let me comment on that.

Westinghouse and Digital Equipment are the largest industrial sponsors in terms of dollar input, but not the largest companies; General Motors is also a sponsor. Without that kind of initial sponsorship, it would have been difficult if not impossible to establish the institute in the first place; nevertheless we do have a number of sponsors who are much smaller companies. There are some relatively small western Pennsylvania companies who are affiliates of the institute, which means that they pay an annual fee of between $15,000 and $50,000 to simply become a member. Those funds are pooled into a common pool and, in return for becoming an affiliate, that sponsor has access to the information, reports, meetings, and so on generated by these pooled funds as well as any inputs from governmental sources that are also public properly, and receives in effect a way of staying in touch with what is going on and being aware, having a window on technology, if you will. So there is a role for the small company in our structure.

Another aspect of that is that we recently have had some discussions with several limited research partnerships in terms of sponsoring work at the institute through that agency, so there is enough flexibility that the balance is really not necessarily tipped as far as it might seem.

Mr. MacKay. But if you contrast what seems to be Government policy in an area that is now critical to the future competitiveness of America with what has been a very successful Government policy, say in agriculture, with the idea that the Government is going to pay the cost of extending information through an extension service to everybody—big farmers, little farmers, everybody—would it not seem that that approach would provide more of a guarantee to society that nobody is frozen out? You are in effect being forced to be an entrepreneur. You have to go out and make sales in order to conduct research, so you are going to go sell to the guy that has got the money. The guy that has got the money, according to the statistics we've got, doesn't necessarily seem to be the guy that's got the ideas. Is not Government policy in this case forcing us more into a mold that's going to require the poor but hungry but brilliant engineer to work for the big company instead of going in on his own, and is that not going to tend to limit innovation in America as he has to fill out forms and wait for committees to decide about his brilliant ideas?

Dr. Pittman. Well, it strikes me that this is the matter that is addressed by the limited research partnership kind of approach, by the various aspects of policy, tax measures, and so on that provide for the availability of venture capital in one form or another. Certainly a large corporation has more financial clout, if you will, to both carry on research internally and also to sponsor it in research or any other research environment.

On the other hand, it is certainly true that the sparks of genius, if you will, some of the more innovative things that happen, do not come out of that environment. I speak with some knowledge because I spent 30 years working for the Westinghouse Electric Corp. before I went to Carnegie-Mellon. There are, in the western Pennsylvania area, a surprisingly large number of small, entrepreneurial companies that have been spawned by the several research activities that exist in that area, not only in universities but also on the part of major corporations. These are situations where individuals have come out from that environment and found ways to do things on their own. So I don't believe that we are in a situation now that would create the kind of danger that you point out.

Mr. MacKay. So you would say, then, the primary source of funding from your standpoint thus far has been NSF and the Department of Defense.

Dr. Pittman. From a governmental source, that's correct.

Mr. MacKay. Yes.

Thank you, Mr. Chairman.

Mr. Walgren. What's the balance of support from the governmental side versus the sponsor side?

Dr. Pittman. About 25 percent of our budget is governmental and the balance is industrial.

Mr. Walgren. I see.

Dr. Pittman. There is a small contribution of seed money from the university itself, which would be on the order of less than 10 percent.

Mr. Walgren. And is that the Government relating to the Robotics Institute or to the university directly?

Dr. Pittman. I am speaking of the Robotics Institute, right. In terms of the university in total, the annual research budget is on the order of $55 million, and of that about a third is from the private sector, from industry, and the balance would be governmental. That's for the university as a whole. The Robotics Institute is much more tipped toward the industrial side.

Mr. Walgren. And at present the institute stands ready to pursue whatever a primary sponsor might feel should be pursued, and then that project is somewhat segregated to that sponsor. What I am questioning is how do you decide what to do and whether there is a decisionmaking board that would be directing the institute toward areas of broad applicability.

Dr. Pittman. Yes. I would take issue with the way you put that exactly. We consciously try to avoid the "researcher-for-hire" kind of situation. We do have a management council structure within the Robotics Institute, consisting of the director, Dr. Raj Reddy, and the senior researchers, who consciously address the overall research strategy, the overall program, its thrust, its balance, and its directions. When a potential research opportunity or a potential project or sponsor is under consideration, it is considered in that light. We consciously also go out and seek sponsorship in areas where we feel we do not have sufficient activity, so there is an interactive mechanism that takes place and we feel that's important because this is the mechanism to ensure that the research work is, in fact, relevant. On the other hand, it requires the input from the research side, too, to be sure that what we see as the appropriate balance and direction is maintained.

Mr. Walgren. Do you have real concerns that the Federal Government may get involved in funding in this area of efforts that are just off the mark, or is it your experience, looking at the way the National Science Foundation and the Bureau of Standards and the Commerce Department and the Department of Defense have been directing Government efforts in areas that clearly ought to be addressed?

Dr. Pittman. Well, in hindsight it is certainly always true in this kind of research environment to look back and find examples of things that were funded that were off the mark, whether it was by Government or industry or anyone else, so in retrospect there are bound to be some failures and misdirections. If there are not, the program is not really aggressive enough.

The mechanism that we feel is important in this respect is this interaction, intercourse between industry and the academic side, the sort of customer-supplier relationship that Dr. Tesar spoke of. If that is pursued and effectively exercised, this can serve to minimize the kind of missteps that we are concerned about, but there certainly will be some.

Mr. Walgren. Well, thank you very much for your testimony. We certainly appreciate it.

Mr. MacKay. Excuse me.

Mr. Walgren. Oh, I'm sorry. Mr. MacKay?

Mr. MacKay. I would just like to get you to comment in any way you think appropriate on the idea that the Federal Government would have a role in trying to look at manpower needs in a 20 or 30 year timeframe. Do you see the shortage of skilled, highly trained manpower as a bottleneck in this whole technology thing?

Dr. Pittman. Yes, it certainly is, both near term and longer term. I believe that one of the pacing items right now in more rapidly advancing robotics and other forms of automation in industry—actually getting it in place and operating in factories—is lack of adequately prepared manpower in industry to do this, so there is a near-term problem in this manufacturing oriented area. Long term there is a potential problem of a very real nature in providing adequate manpower not only to carry on the kind of research work that's going to keep us in the forefront in this race, literally, but also to provide the recipients for that technology within industry. This can perhaps be the greatest threat to the effective transfer of this technology to useful implementation, so there is a very definite manpower consideration there.

Now what the Federal role should be, there could be some debate on because there certainly is the real danger that you could overreact, create supply-demand imbalances and so on, but it seems to us that at the present time there is a definite shortage in both these scores and that encouragement to get promising young people to pursue this line is very much in order, so any means that would do that at the present time certainly seems to be very appropriate.

Mr. MacKay. Thank you, Mr. Chairman.

Mr. Walgren. Thank you, Mr. MacKay.

Well, we certainly appreciate your testimony and especially your being a resource to the committee. Clearly the Robotics Institute is an example of the private sector showing a very constructive direction to go, and doing that before the Federal Government was able to agree on any specific structural initiatives in that area. We do look on you as a prototype of efforts that we might strengthen, so we will look forward to talking with you in the future about how the institute is progressing.

Dr. Pittman. Thank you very much, Mr. Chairman.

Mr. Walgren. Thank you, Dr. Pittman.

We have been joined by the chairman of the full committee, Mr. Fuqua, who has been interested in this area over a period of time and is the sponsor of one of the most prominent bills and suggestions, H.R. 4047. We specifically moved this hearing from the full committee room down to this room because we thought it might be a conflict of interest to have your portrait up in back of the chairman. [Laughter.]

Mr. Walgren. I now realize that we are surrounded by more pictures of things that you may be more directly responsible for than almost any other Member of Congress, so we have sort of gotten out of the frying pan into the fire as far as being in a room that testifies to your accomplishments in the Congress.

So we are, as any subcommittee chairman would be, very delighted you're here.

STATEMENT OF HON. DON FUQUA, A MEMBER OF CONGRESS FROM THE STATE OF FLORIDA, AND CHAIRMAN, COMMITTEE ON SCIENCE AND TECHNOLOGY

Mr. FUQUA. Well, thank you, Mr. Chairman, and I certainly appreciate your kind remarks, as always. Let me say that I hope the bill can stand on its own and not be intimidated by me.

Mr. Chairman, I do appreciate your cooperation in holding these hearings. I think that the United States must improve its methods of manufacturing. What most needs to be done is up to industry to decide but there is a Federal role in supporting research, helping ensure that education is available, and stimulating industry to get on with the job, and this hearing that you are holding today regards legislation to improve the needed Federal role.

As a principal sponsor of both the bills on automated manufacturing and robotics which are before you today, I urge you to favorably consider this legislation and come forth with a bill that contains the best elements of these bills. I will explain my bills to you but, before I do, I want to take a look back at the big picture of what these bills are all a part of.

On a global level we have a world of finite natural resources and increasing population, and in order to have any hope of providing a comfortable life for the world's people we must make continually more effective use of resources which are getting continually scarcer. There is only one way to accomplish this—through improved technology. The area of manufacturing is ready, in my view, to move quickly ahead in technology and we should take advantage of this opportunity.

On the national level, the United States is faced with stiff competition from our friends abroad in nonmilitary goods. Japan in particular has mounted a concerted effort to introduce new technology into manufacturing. They have already had a big lead on the United States in the applications of robotics to manufacturing.

Within Congress there has been a great deal of concern with the need to get science and technology into the economy more effectively. Our Committee on Science and Technology has pursued issues of science and technology for the economy vigorously for years, and you and your subcommittee, Mr. Chairman, have taken the lead for this committee in this area. Last year you were the leader in our consideration of antitrust relief for joint research. This year you have looked at patent policies, ideas for technology foundation, and now automated manufacturing, in addition to your extensive work in other areas.

In much congressional action on issues of science and technology, we have been able to avoid being partisan. In May the House voted unanimously in favor of the bill providing for antitrust relief for joint research and development. Senator Gorton and I have been in agreement on the need for attention to manufacturing technology, and I hope this spirit continues because the country needs it. This is the spirit of being practical about what is required and working to provide it.

Let me now turn to legislation on automated manufacturing and robotics. I have been interested in these issues for some time, and many of the people in this room have consulted with me and me with them more, and I was on the receiving end of a lot of information about that. In 1979 we sponsored a conference on technology and innovation for manufacturing. My thinking is that several kinds of government actions can spur automated manufacturing.

Last September I introduced a package of three bills to provide Government action. The first of these bills, H.R. 4046, would stimulate the leasing of automated manufacturing systems and robots. That bill has been referred to Mr. LaFalce's subcommittee. The second bill, H.R. 4047, is before you today and I will have more to say about that later. The third bill, H.R. 4048, would provide tax credits for the purchase of automated manufacturing equipment or robotics, and was referred to the Committee on Ways and Means and so it is not before us.

When I introduced these bills, I put an explanation of them in the record, and I would like at this time to ask that that explanation be part of your hearing record.

Mr. WALGREN. Without objection.

[Material to be supplied follows:]

[From the Congressional Record, Friday, Sept. 30, 1983]

BILLS ON AUTOMATED MANUFACTURING AND ROBOTICS

(By Hon. Don Fuqua)

Mr. FUQUA. Mr. Speaker, today I am introducing a package of three bills to stimulate the development and use of automated manufacturing systems and robots. These bills are the Robotics and Automated Manufacturing Systems Research and Education Act of 1983, the National Robot and Automated Manufacturing Systems Leasing Act of 1983, and an unnamed bill which provides a tax credit for the purchase of this equipment. I am joined in introducing these bills by my colleagues, the Honorable Al Gore of Tennessee, the Honorable George E. Brown, Jr. of California, the Honorable Buddy MacKay of Florida, and the Honorable Sherwood Boehlert of New York. I invite all Members of the House to join in cosponsoring any or all of these three bills.

For the past 4 years the Committee on Science and Technology, particularly through our Subcommittee on Science, Research and Technology, has been investigating innovation and productivity in the United States. We have been informing ourselves broadly through oversight hearings, taking legislative initiatives when we believed they were desirable, and cooperating with other committees of Congress. In June the Subcommittee on Science, Research and Technology held 7 days of hearings jointly with the Task Force on Education and Employment of the House Budget Committee on the subject of technology and employment. In October the same subcommittee is marking up a bill to encourage joint research and development work among private firms.

Several examinations of automated manufacturing and robotics have been included among the committee's studies, the largest of which were a 2-day seminar on technology and innovation for manufacturing which I sponsored in 1979 and 2 days of hearings on robotics held by our Investigations and Oversight Subcommittee chaired by the Honorable Al Gore in 1982.

The country that leads the world in the technologies of manufacturing has the potential to lead the world in manufactured products by applying those technologies. Unless the United States makes a major effort now, that country is going to be Japan. The Manufacturing Studies Board of the National Research Council reported in 1981 that the population of robots in Japan was 6,000 while the United States had 3,500. In 1982 at our Investigations and Oversight Subcommittee hearings, investment analyst Paul Aron reported 14,246 Japanese robots versus 4,700 in the United States. Mr. Aron's report which appeared this year notes 31,900 in Japan and 6,301 in the United States. In the broader field of automated manufacturing—where several robots or other automated machines are integrated into a system to produce an entire product—the United States faces an equally strong challenge. Earlier this year I visited the Fanuc robot plant in Japan where the people go home at night and the plant keeps working.

To develop the technologies of robotics and automated manufacturing, research and development is needed. Most of this research and development must be in the private sector to be effective; it must be tied to specific rebotic and automated manufacturing products. There is a Government role, however, in developing such equipment for its own specialized uses—such as in space, defense, and radioactive materials handling—and in supporting research and development which is not product-specific and is not likely to be pursued by industry because of its long-range or risky nature. to allow commercial technology development there is also a need for people trained in that technolgy. The limiting factor in electronics and computers now is people. Without expanded education in robotics and automated manufacturing these fields will also be limited by the availability of trained American personnel. The Robotics and Automated Manufacturing Systems Research and Education Act of 1983 provides for a Federal role in these areas which I believe to be the right role.

Robots and automated manufacturing are new technologies and their introduction in a company involves both fear of the unknown and risk of failure. To offset fear and risk the Federal Government can provide financial incentives and make these technologies more easily available. That is what the tax credit and leasing bills I am introducing to day would accomplish.

From the June hearings on technology and employment, it is clear that robots and automated manufacturing equipment will displace workers in some job specialties. But the displacement likely to be caused by new technology is a small fraction of the unemployment that will occur if our industries are not competitive. As a nation we must find a way to introduce new technologies, such as robots and automated manufacturing systems, and protect the welfare of our workers at the same time. This is a position both labor and management can support and did support at our recent hearings. The legislation I am introducing today does not deal with the issues of displacement and retraining, I am not persuaded legislation is needed. I do plan to study this issue further, however.

Summaries of the three bills follow:

"ROBOTICS AND AUTOMATED MANUFACTURING SYSTEMS RESEARCH AND EDUCATION ACT OF 1983

"A. RESEARCH, H.R. 4047

"1. The National Science Foundation (NSF) is authorized to fund centers for industrial technology devoted to robotics and automated manufacturing and to fund project grants in the same fields. The centers are intended to be established through cooperative efforts between universities and industry. Areas of emphasis for both centers and individual project grants should include: manufacturing processes, control systems, sensors, sensory data analysis, software development, kinematics and dynamics; machinery design, teleoperation, artificial intelligence, human argmentation and prosthesis, and human and economic factors associated with the introduction of robots and automated manufacturing systems into society

"2. A Federal Research Center on Robotict and Automated Manufacturing is established at the National Bureau of Standards (NBS). This Federal Center would focus its research on measurements and standards required in Robotics and automated manufacturing systems as well as systems integration, reliability and performance.

"3. The Department of Commerce is directed to promote the formation of limited research and development partnerships in the area of robotics and automated manufacturing systems. Such partnerships would require no Federal participation. The Department is already engaged in promoting partnerships, though not necessarily in these areas.

"B. EDUCATION AND TRAINING

The NSF is authorized to support the education and training of personnel needed in robotics and automated manufacturing. Support would be provided for graduate fellowships, undergraduate scholarships, instructional equipment, curriculum development and post-doctorate fellowships.

"C. PROGRAM REVIEW

"The National Research Council is directed to rview Federal efforts in robotics and automated manufacturing and report its findings and recommendations.

"D. AUTHORIZATION AMOUNTS

[In millions of dollars]

	Fiscal year—		
	1984	1985	1986–90
NSF Research	20.00	40.00	50.00
NBS Centers	10.00	10.00	10.00
DoC R&D partnerships	2.00	2.00	2.00
ASF education and training	5.00	7.00	10.00
Program review	0.25	0.25	0.25
Total	37.25	59.25	72.25

"NATIONAL ROBOT AND AUTOMATED MANUFACTURING SYSTEMS LEASING ACT OF 1983

"A. LEASING CORPORATION, H.R. 4046

"A National Robot and Automated Manufacturing Systems Leasing Corporation is authorized to be established. The Federal government would set the Corporation up, but the Corporation would be a for-profit private firm rather than a government agency. An appropriation of $1 million is authorized to start the Corporation in business, but it would be repaid to the government.

"B. LOW INTEREST LOANS FOR LEASING

"The Federal government would pay one-third of the interest due on loans made for the leasing of robots or automated manufacturing systems to small businesses or for short terms, making such equipment more economical to acquire. An authorization of $20 million per year for the Federal share of interest is provided for fiscal years 1984 through 1990.

"ADDITIONAL TAX CREDIT, H.R. 4048

"A tax credit of 10 percent (in addition to other tax credits) would be allowed for the purchase of robots or automated manufacturing systems."

Mr. FUQUA. Although these bills present a coherent program, each of them stands on its own and I doubt very seriously that all three will be enacted in this Congress, but the passage of H.R. 4047 alone would be a strong step forward.

Last November, in order to put Senator Gorton's bill before the House, I introduced it as H.R. 4415, and it is also before you today. Senator Gorton, I understand, will be testifying tomorrow and will be describing his bill to you himself, so I will not get into the specifics, but let me only say that many of the provisions of his bill are similar to the provisions of H.R. 4047, so it has got to be a pretty good bill.

Now I want to tell you about H.R. 4047. This bill is called the Robotics and Automated Manufacturing Systems Research and Education Act of 1983. I would suggest the title be amended to say 1984. This bill provides for both R&D and education. In R&D, the bill proposes activities for the National Science Foundation, the National Bureau of Standards, and the Department of Commerce.

The NSF is authorized to fund centers for industrial technology devoted to robotics and automated manufacturing and to fund projects and grants in these fields. The centers are intended to be a cooperative effort between universities and private industry. Areas of emphasis for both centers and project grants would include manufacturing processes, control systems, sensors, sensory data analysis, software development, kinematics and dynamics, machinery design, teleoperation, artificial intelligence, human augmentation and prosthesis, and human and economic factors associated with an introduction of robotics and automated manufacturing systems into society.

The bill would establish Federal Research Center in Robotics and Automated Manufacturing at the National Bureau of Standards. This Federal center would focus its research on measuring and standards required in robotics and automated manufacturing systems, as well as on systems integration, reliability, and performance. The bill would direct the Department of Commerce to promote the formation of limited R&D partnerships among private participants in the area of robotics and automated manufacturing systems. Such partnerships would involve no direct Federal participation.

In education, the bill provides for a role for only the National Science Foundation. The NSF is authorized to support the education and training of personnel needed in robotics and automated manufacturing. Support would be provided for graduate fellowships, undergraduate scholarships, instructional equipment, curriculum development, and postdoctoral fellowships. Much as is the case with other high technology areas such as electronics and biotechnology, there will certainly be shortages of trained people to do the jobs that will be available in automated manufacturing if we do not act to provide training.

Finally, the bill would require a review of the overall program by the National Research Council. The bill would provide authorizations for 7 years amounting to $37 million for the first year, $59 million for the second, and $72 million in each of the following 5 years. The program would sunset automatically if these authorizations were not renewed.

Mr. Chairman, under the able guidance of Senator Gorton, the counterpart bill in the Senate has already been passed. As I said at the start of my testimony, I hope under your able leadership that this legislation will be favorably considered. The progress of technology is essential to everyone. This legislation provides a sensible Federal role in encouraging the technologies of robotics and automated manufacturing.

I will be happy to answer any questions if I can answer them. Otherwise, there are some experts sitting right behind me.

Mr. WALGREN. Well, thank you very much for that testimony.

How do you apportion the funds that might be able to be directed in this area between the Federal Robotics Center and the centers that would be in the university community and in private industry?

Mr. FUQUA. Well, I think that would be the agencies that would be responsible for these. We are not trying to micromanage them. Also, it would be supervised, as I mentioned, by the National Research Council, and that would be from an oversight standpoint. I think the agencies involved would be able to make that determination of how the funds would be appropriated.

Mr. **Walgren**. And the education component would be the same at that point——

Mr. **Fuqua**. Yes.

Mr. **Walgren** [continuing]. And you would be balancing those funds among those three functions, then.

Mr. **Fuqua**. I think it would be difficult to have a hard line at this juncture. Later we might be able to more specifically identify the areas that need further attention, but I think as we move further into the operation of the program, the 7-year program, then we may be more specific. At the initial stages of it I'm not sure that we can really pin down how much should go into graduate fellowships versus some of the other needs of the program.

Mr. **Walgren**. And you, as I understand it, are staying away from picking individual industries like the automotive industry or the steel industry or electronics, but——

Mr. **Fuqua**. Well, they are all candidates, but I think that also should be determined and we are not trying to force this on anybody, but I think all of those industries—and I outlined a lot of areas that could utilize automated and robotic machinery—I think it would be up to those industries to make known their wishes or desires. We are not trying to, through Congress, mandate to the automotive industry or the steel industry that they should automate.

However, the economics of the situation, as I mentioned, has automated a great portion of the automobile industry and made it much more competitive and strengthened it economically, and I think that will probably be true of other industries, particularly steel and some of the others.

Mr. **Walgren**. We would be focusing in sort of a more generic way, would we not, rather than by picking an industry and trying to strengthen that industry. We would avoid that kind of conflict.

Mr. **Fuqua**. I think that would be a very bad way to go, for the Congress or the Government to decide that this specific industry needs help and we are going to help you whether you want it or not. I think the industry has to make that decision themselves, but we would be available and I think it would be attractive to all industries. How could we say we would pick the automotive industry, over say the utility industry or power industry, or if you were manufacturing motorcycles as the Japanese are doing, with automation?

So I don't think we could sit here and say we will choose one industry someplace above somebody else, but I think industry, once we get in—and we need to get in as many industries as we can—once they see the benefits of it, those in that industry, whether it be in agriculture or other types of industries, I think then they will realize the importance of it. Agriculture is already automated, a very highly automated industry, and it didn't take farmers very long to understand that they needed that in order to be competitive because of cost of production.

Mr. **Walgren**. Well, it certainly seems to make sense because I'm sure of a much more ready consensus on supporting areas of general applicability than specific applicability, even though I come from an area that would sure like to see some specific applicability.

Mr. FUQUA. Well, I think there could be. The steel industry is a very vital industry to this country and I know of your concerns about that. I think it would be a prime candidate, but I don't think we should single out any one industry. It would be available for steel, aluminum, or whatever that might see fit to participate in one of the programs, and I would encourage them to do that.

Mr. WALGREN. I guess what I'm driving at is, we certainly should be in a position of saying we're not picking one winner or one loser or directing the outcome of the private marketplace. Rather, we are saying that there is a broad need in this area that is applicable in all or a wide, wide range of the American economy, and if we put the scientific know-how in place to satisfy that need in all those areas, we would be doing something that no one should have great problems with.

Mr. FUQUA. And I think the economic incentives will be there to make it attractive to industry, but right now we have not provided the catalyst to get this information and this know-how through the training in our colleges and universities or even understanding it in the Government out in the field. It's a field that I don't profess to be an expert in, but there are many experts who have vision and who see that this is a field that has great potential.

I mentioned some of the social concerns which we must be aware of but, on the other hand, I think just like when we stopped the buggy whip factories and the candlemakers, people shifted to other jobs and they were made available to them. Had we continued to prop up and support through various methods buggy whip and candle manufacturers, we would probably be a very backward society today. We did not do that. The economics took force, and the people that shod the horses started changing the tires on the automobiles. The candlemakers started making light bulbs, and so these types of things certainly are societal changes and we must not sweep that under the rug, but I think that in the long run society will be much, much better off in this country and the world economy that we live in will be much more competitive.

Mr. WALGREN. Well, thank you very much.

Mr. MacKay?

Mr. MACKAY. Yesterday we heard representatives from the Department of Commerce basically say that they were opposed to the idea of Government getting into this, and I think that reflects the fundamental philosophic position of the Reagan administration, that the Government should be involved in basic research. You are basically suggesting in this legislation that there is a role for Government in generic technology research.

Mr. FUQUA. Well, there is a perception, "Let George do it." That has been a perception that has been around for a long time, "George" being industry, but George ain't going to do it. That's where the Government needs to be that bridge to get that technology to "George," being industry, so that he can do that. That is an unfortunate perception that's held by many people publicly in this administration, not necessarily all privately.

Mr. MACKAY. Thank you.

Thank you, Mr. Chairman.

Mr. **Walgren**. Mr. Lundine?

Mr. **Lundine**. When my chairman says that he has got some bills we ought to move on, I don't have any questions. [Laughter.]

Mr. **Fuqua**. Well, let me say in Mr. Lundine's defense that he has been very active in this area on other committees and on this committee, and I know his deep feelings about this. It has been an area, particularly in innovation and productivity, that he has been very interested in, and I applaud him for the work that he has done over the years in those areas.

Mr. **Walgren**. I will be curious to see what the answer to this is: Dr. Tesar had charts of Government investment in different lines of manufacturing, and we all know the heavy investment in aerospace governmentally, the heavy investment in agriculture, but also at least in this instance there was very heavy investment of governmental effort in heavy manufacturing, and that seemed to have an electrical generation and power component to it. Then when you turn to light manufacturing, the Government just disappeared. The question would be, why did the Government disappear? Why is it so glaringly present in its supportive role in these other very important parts of our economy and so strikingly absent in this other area.

Mr. **Fuqua**. Well, let me cite you an historical example, and that's in aviation. In World War I the United States found that they did not have any airplanes to use in the war, and the enemy had interdicted aircraft. It was the first time an airplane had been used in a war. We had to buy our airplanes from Great Britain and France. They did most of the pilot training for our pilots. The Congress decided after World War I that no longer would we be dependent on foreign sources for this critical thing, so they established a National Advisory Committee for Aeronautics. That later became the "A" in NASA, and it's a classic case of the Government doing a lot of the basic research and some of the testing with joint ventures, cost-sharing with industry. Up until recent years, just a few years ago, the United States dominated the world, commercial aviation and general aviation. That has changed somewhat in the last few years, and there were efforts earlier in this administration to reduce severely—and you recall that in our committee, and the fights that we had with the administration over funding—basic and applied research in aeronautics, engine development, materials and design. We prevailed, and now the administration has come back and said it's a great idea, and we were for it all along. But that's a classic case of where Government involvement has been a great benefit economically to this country. We can use that as an example of how it has worked.

We are in the same situation. I did not see Dr. Tesar's statements today. Unfortunately, I was presiding over another hearing, but I have seen them before and I am sure they are very similar to the ones that I have seen before with very alarming statistics as to what's happening, particularly in small manufacturing. I think we cannot ignore that fact.

Mr. **Walgren**. Mr. Boehlert, would you like to——

Mr. **Boehlert**. Thank you, Mr. Chairman.

I want to thank the distinguished chairman of our committee for being here, and I want to tell him that in the spirit of bipartisanship I am with you 100 percent on these bills.

One of the good fortunes I had as a freshman was being assigned to this committee under your leadership, and it is an exciting thing for me to be involved in legislative initiatives like this because I believe, as the star of that Broadway play believes, we've got to be concentrating on tomorrow. You've got me, Mr. Chairman. I'm with you.

Mr. FUQUA. Thank you very much. I knew you were very enlightened, Mr. Boehlert.

Mr. WALGREN. Well, thank you very much. You can count that the committee will be focused on this.

Mr. FUQUA. Thank you.

Mr. WALGREN. The next witness, Dr. Allen Rosenstein, is a professor of Engineering at the University of California at Los Angeles and chairman of Pioneer Magnetics, Inc., also based in Los Angeles, CA. Dr. Rosenstein, we certainly welcome you to the committee and we appreciate your being available to us. There are relatively few people who have the direct experience that you do in both the private sector and the academic sector and have given as much thought to where we ought to be going as you have, and the committee certainly appreciates your being willing to come and testify to us, so please proceed.

STATEMENT OF DR. ALLEN B. ROSENSTEIN, PROFESSOR OF ENGINEERING, UNIVERSITY OF CALIFORNIA AT LOS ANGELES, AND CHAIRMAN, PIONEER MAGNETICS, INC.

Dr. ROSENSTEIN. Mr. Chairman, members of the committee, it is really a pleasure to be here and I always enjoy following Dr. Tesar. I learn so much from his work and the things he has to say.

Our company sells abroad and, as a consequence, we are keenly aware of international competition. In the 1960's a study which we conducted at UCLA concluded that structural defects in our basic American institutions and important shifts in our cultural values and in U.S. educational policies guaranteed an ever-eroding industrial base and a long-term decline in our relative quality of life. Our exploding U.S. trade deficit, which is projected to exceed $125 billion this year, would seem to confirm these predictions of nearly 20 years ago.

Unfortunately, even today there is a greatly improved but still limited recognition of the complex causes of our industrial demise. It's very unfortunate. There isn't one single factor that's giving us difficulty. There's a whole complex of factors, and unless we recognize all of them we're not going to fashion mechanisms and bills which will properly turn aside the decline that we are experiencing.

Haphazard attacks upon current local manifestations of the much larger problem will only dissipate our resources. There is also a great need to recognize that we have a dynamic situation. If we have a static solution, no matter how good it is at the moment, it is absolutely guaranteed to fail when it is faced with the dynamics of our society.

Implicit in many of the bills that I read before the Congress today is a belief that leadership in basic research and technological innovation will ensure industrial competence and international trade competitiveness. The bottom line, of course, is trade competitiveness. We know that in modern society we have an international marketplace. We are part of that marketplace, in contrast to where we were 50 years ago when we had a closed society. If we are to maintain our quality of life we must maintain our competitiveness in the international marketplace.

Now unfortunately this common perception, this current wisdom is absolutely untrue. Basic research, technological innovation, industrial competence, and international trade competitiveness are largely independent and different activities. They have very different constituencies, different processes, different performance criteria, and in particular they respond to very different sets of national policies.

Competence in one activity is simply not a guarantee of success in the others, and there are just hundreds of examples to prove this fact. For example, the Boeing Aircraft Co. is probably the finest aircraft engineering, manufacturing company in the world. There is no question about their industrial competence. However, they have been losing out consistently over the years in the international aircraft market, and we have lost a great deal of foreign exchange because of the peculiarities of international financial and interest rate policies. It had nothing to do with their manufacturing competence. Trade, interest, and financing policy foreclosed Boeing's ability to compete in important markets.

U.S. Steel we all know was dismantled by Japan using technology invented here in the United States but never applied. The trickle-down theory of basic research, which claims that throwing more money into basic research will somehow trickle down into industrial competence and international trade competitiveness, does not work in fact. If it were true, we would not have this strange anomaly where the United States leads the world by a large margin in both Nobel science awards and trade deficits. If anything, on the average the data would indicate that there is a strong negative correlation between scientific capability and industrial competence. I always hasten to add at this point that some of my best friends are scientists and I wish them well.

Our prepared statement addresses not only the merits of the excellent bills that we have been asked to review but also points out an interesting pattern that could provide substantial operational efficiencies. The basic operational functions to be performed by H.R. 2525, 1234, 481, and 4361 are presented on page 3 of our written testimony in a function spread sheet. (I'm sorry I don't have something to put on the board.) We believe that mechanisms that would create and facilitate consistently successful public programs must be capable of four basic activities or functions.

The first is the ability to acquire a comprehensive international data base. The second is that of problem anticipation, analysis and the consequential assessment of alternatives. The third is public review and consensus generation, and the fourth is the implementation of national policies that cannot be facilitated within existing public/private institutions.

If we glance at that spread sheet, we can see that H.R. 2525 addresses two functions, analysis and public review. H.R. 1234 has the National Academies developing a data base, then identifying strategic alternatives, and finally getting public advisory committees to develop a public consensus. H.R. 481 provides an Office of Technology Policy and Analysis to look at the technology policy analysis questions. Then there are a number of excellent offices for technology policy facilitation. The bill is slightly limited on its data base generation and its ability to provide public review. H.R. 4361 concentrates largely on technology implementation. However, Congressman LaFalce has introduced a companion bill to address many of the other functions.

Besides the four bills offered by the committee, I have taken the small liberty of reviewing another bill, 4245. This bill is designed to provide all four basic functions in an effective, mutually supporting fashion. In addition, 4245 addresses the fundamental causes of our present industrial discomfort and would provide an ongoing mechanism for the creation and facilitation of national policy, including especially those policies required for reindustrialization.

It was interesting to me, as I sat here and listened to other people testify, that time and time again the word "policy" would come up. I would like to advance the premise that it is this ability to address policy in an intelligent, organized, and coherent fashion which is largely missing in many of our institutions. The point that must be made is that improved industrial competitiveness, particularly in a dynamic environment, requires a large set of mutually consistent national policies, including education policy, taxation policy, savings, regulation, environmental policies, et cetera.

There is considerable public debate, as an example, about the relative merits of high-tech industry versus smokestack industry as a source of employment. I would hold that this is an example of lack of analysis and study of the basic data. It is almost a nonsense discussion which does not recognize the ultimate problem that the Nation must resolve before the end of this decade. All of industry, high-tech and smokestack, will not employ a significant percentage of the working population by the year 2000. If U.S. employment trends continue to follow the trends of the past 5 years, manufacturing will only employ 8.3 percent of our entire working population at the end of this century, which is only 16 years hence, and of course 8.3 percent is I think slightly less than the present unemployment rate. Therefore all of manufacturing in the year 2000 won't put all of our presently unemployed back to work.

Now I would like to see if I can illustrate some of our serious structural deficiencies by attempting to demonstrate how a properly constituted foundation could provide a public support function that would give private enterprise greater freedom of action and the ability to more effectively meet foreign competition in an arena free of Government domination. The example I would like to use is the unmanned garment factory, because I will make a prediction today that within 10 years we are going to have in this country a major problem in our garment industry. They employ about 2.8 million people in the garment and the textile industry and, since textiles are largely automated, most of these people are in the garment industry. This could be a classical situation in which a national policy facilitating foundation could help a thoroughly dispersed and fragmented industry resolve a major threat from abroad.

It turns out that some years ago, 2 to 4 years ago, Japan and Sweden independently both funded major programs to develop unmanned garment factories. One country put up $66 million and I think the other country put up about $85 million. These factories, with practically no employees, will turn out garments on any preprogrammed arrangement. They could turn out one garment at a time; they could turn out one size at a time. They are completely flexible garment manufacturing centers, As an engineer I can tell you that they are technologically feasible. The probability of their success is very high, and it's obvious that when this occurs there is going to be a major impact upon our industry.

Now what functions could a foundation or the Government play in this case? Well, it would seem to me that since this type of knowledge is generally available, the foundation could have an international data acquisition system which would acquire data about these programs as they are instituted and then follow that up with an analysis and an assessment section which could then provide an early warning system for U.S. industry. Having recognized the pending problem from our own international data base, the Government could then convene meetings of industry to show what the probable alternatives are and look for logical courses of action.

It would seem that we have three courses of action before us right now. The first is a decision as to whether we wish to maintain a capability for manufacturing automatic unmanned garment industry machines. We have a company called Singer Sewing Machine which builds, I think, a lot of garment manufacturing machinery. In fact, interestingly enough, they were the ones who conceived the concept of an unmanned garment factory, and I believe they were not large enough to actually implement the program itself. I understand the Swedish and Japanese programs are modeled about the initiative that Singer started. We could decide first of all if we wanted to maintain the equipment manufacturing facility, and what support, is necessary. Whether a consortium could be put together which would enable us to maintain this machinery capability in the country.

A second decision that should be made is as to what would happen to the garment industry itself. It seems obvious that a large percentage of the 2.8 million people now engaged in this activity are, over a period of time, going to become redundant. The question then is whether we wish to maintain a garment industry of any consequence in this country at all. It would seem that we would probably have to have a reorganized garment industry. It might be that we could finance garment centers. For example, there are probably only one or two light bulb manufacturing machines in the country. They appear under different labels, but the machinery is so efficient that we can't afford to have a dozen companies actually manufacturing light bulbs. It's entirely possible that the analysis would show that there might be two or three flexible garment manufacturing machine centers in this country, and they might call for a consortium of banks, industry, Government to finance them. If we decide we want to retain this particular activity, it should be an informed decision.

We may decide we don't want to have a garment industry in this country, which then brings us to the third set of decisions: What is going to be done to or for the 2.8 million people who I predict have a very, very high probability of becoming redundant?

A fourth course of action would be to ignore the whole situation, allow nature to take its course, and go through the same process in the garment industry that we had in the steel industry, in the machine tool industry, in the automobile industry. I would contend that every country has a limited number of opportunities and if you let them all go by, I think the results are predictable.

I would like to close on a more optimistic note with two observations. First of all, each of the proposed bills addresses a very important problem and will satisfy significant needs that have been neglected for too long.

Second, I would only add that the spread sheet would indicate that each of these bills, which are important, handles a part of a larger problem. I would think we should consider whether we could profitably entertain one initiative to combine the best features from each bill.

Now, finally, I would like to come back to the future role of the Government by quoting from a paper by a Mr. Thomas Murrin. As president of Westinghouse's Energy and Advanced Technology Group, which is a very successful Westinghouse Division, Murrin has been featured in a Time magazine article as one of the outstanding industrial managers in our country. Murrin says:

> Meeting the Japanese challenge is beyond the reach of any one company. Even if every major corporation in the U.S. were to undertake programs to improve their productivity and competitiveness, their efforts would not suffice against Japan's national industrial policy.

He goes on to say:

> When Government, management, labor, and academia all work in a cooperative and complementary fashion towards shared objectives, the most difficult challenges become manageable. What is lacking is an effective mechanism to bring the leaders of these facets of society together on neutral ground in pursuit of common goals.

Finally, he adds:

> Therefore, we in the United States need to consider adopting a consensus-based policy formulation mechanism.

Now I contend that in this last sentence Murrin has presented the single most important challenge faced by the Government for the balance of this century: how to create a consensus-based policy formulation mechanism that will provide a truly neutral ground, recognized and accepted by all elements of our society.

Thank you very much.

[The prepared statement of Dr. Rosenstein follows:]

TESTIMONY

of

Allen B. Rosenstein, P.E.

Chairman, Pioneer Magnetics, Inc.

Professor of Engineering
Systems Engineering Dept.
University of California at
Los Angeles

on

HR 2525 , HR 1234, HR481

HR 4361, HR 4245

Before the

Subcommittee on Science, Research and Technology
of the Committee on Science and Technology

U.S. House of Representatives

June 12, 1984

STATEMENT OF ALLEN B. ROSENSTEIN

Mr. Chairman and members of the Committee:

I am Chairman of the Board of several high technology electronics companies and a Professor of Engineering at UCLA. Please accept my thanks for the opportunity to testify at these hearings on Technological Innovation in the United States. The sharply increasing Congressional interest in the industrial well being of our country is especially timely. In the 1960's a study which we conducted at UCLA concluded that structural deficiencies in our basic institutions and important shifts in our culture and in U.S. educational policy guaranteed an ever eroding industrial base and a long term decline in our relative quality of life. (Reference 1 appended). A growing U.S. trade deficit, expected to exceed $125 billion in 1984 would seem to confirm the predictions of nearly 20 years ago.

To evaluate the potential effectivity of the proposed bills, let us first consider function and structure. After that we examine the more difficult and abstract question of long term fit with the nation's basic needs.

FUNCTION EVALUATION

Assuming that form (structure) follows function, it is our premise that mechanisms that would create and implement consistently successful public programs must be capable of four basic activities or functions. These are:

1. Creation of a comprehensive high quality information and data base that is readily accessed;
2. First rate independent anticipation and analysis of national problems and opportunities and the assessment of alternatives;
3. Socially representative public review of alternatives to generate national consensus, and
4. Facilitation and implementation of those policies and programs for which there are no presently existing suitable organizations.

A spread sheet has been included to illustrate the proposed functions and structure of HR4361, HR481, HR1234 and HR2525. When the totality of the attributes of the preceeding bills are taken together, they cover rather completely the above four functions. We also observe that another bill, HR4245, offers a vehicle in which all of the activities of the bills under review can be well served.

FUNCTION & IMPLEMENTATION SPREAD SHEET

BILL NO.	HR 4245 (BROWN)	HR 4361 (LaFALCE)	HR 481 (BROWN)	HR 1234 (BROWN)	HR 2525 (PASHAYAN)
NAME	National Professions & Technology Foundation Act	Advanced Technology Foundation Act	National Technology Foundation Act	Economically Strategic Industrial Research and Development Act	National Commission on Technology Innovation and Industrial Modernization
PURPOSE	National Policy Creation and Facilitation	Promote Advanced Technology	Advance Nation's Technology	Identify and Develop Economically Strategic. Technologies	To propose a National Industrial Strategy
STRUCTURE	Foundation	Foundation	Foundation	National Academies study (one time, 3 year)	Commission (1 Yr.)
FUNCTIONS	IMPLEMENTATION				
I. DATA BASE FOR POLICY MAKING	National Information and Statistics Policy Development-coordinated by National Technical Information Service			Academies	
II. ANALYSIS, PROPOSAL, ASSESSMENT	Office of Policy, Analysis & Assessment		Office of Technology Policy & Analysis	Academies to Identify Strategic Technologies	Analysis of Relevant Factors. Recommendation of Industrial strategies
III. PUBLIC REVIEW AND CONSENSUS GENERATION	Independent Public Councils			Advisory Committee for each technology	To recommend advisability of a permanent and independent Advisory Agency for policy relevant to a coordinated National Industrial Strategy
IV. IMPLEMENTATION AND FACILITATION	1. National Programs Office-Cooperative D&R 2. Institutional & Human Resource Development 3. Centers for Industrial Technology:Generic R&D 4. Small Business Office 5. Professions & Technology Counterpart of Agriculture Extension 6. Office of Professions 7. Intergovernment Technology and Professions Delivery Systems Office 8. National Bureau of Standards 9. Patent and Trademark Office 10. National Technical Information Service	1. Cooperative R&D 3. Generic Industrial Research 5. Federal Industrial Extension Service	1. Office of National Programs 2. Industrial & Human Resource Development 3. Centers for Industrial Technology:Generic R&D 4. Small Business Office 6. Office of Engineering 7. Intergovernmental Technology Office 8. National Bureau of Standards 9. Patent and Trademark Office 10. National Technical Information Service		

Taking each bill in turn:

HR 2525: The National Commission on Technological Innovation and Industrial Mobilization Act.

Offers deep insight into the spectrum of issues that must be considered if industrial competence is to be improved. The final report of the one year commission would address the central question: Should there be a permanent advisory agency for policy relevant to a coordinated national industrial strategy? This question deserves public review and debate by an independent commission. HR 2525 calls for analysis and assessment followed by public review. Should a permanent advisory policy agency be created, the agency would presumably develop a policy data base and consider program implementation.

HR 1234: The Economically Strategic Industrial Research and Development Act.

Asks the National Academies to identify strategic technologies and build a suitable data base for each. Independent public review is provided by an advisory committee for each technology.

HR 481: The National Technology Foundation Act

Through the Office of Technology Policy and Analysis would provide a very important technology policy analysis and assessment capability. Extensive, well-conceived offices and agencies are brought together in the Foundation to facilitate and implement national technology policy. The structure and functions of HR481 are very close to HR4245 with HR481 restricting itself to technology while HR 4245 considers technology policy as an important constituent of national policy. HR481 has limited provision for a comprehensive industrial or technology data base and little means for public review or consensus generation.

HR 4361: The Advanced Technology Foundation Act

Concentrates largely upon implementation of industrial policy. Cooperative programs, generic industrial research and the Federal Industrial Extension Service are important and worthy concepts. We should observe that a companion bill has been introduced by Congressmen LaFalce to cover the three functions not addressed by HR4361.

HR 4245: The National Professions and Technology Act -

•Introduced by Congressman George Brown with 13 sponsors, will provide an ongoing mechanism for the creation and facilitation of national policy including especially those policies required for industrial revitalization. References (2) and (3) describe the bill itself while reference (1) provides a detailed explanation and justification for the creation of a National Policy Facilitating Foundation instead of a more limited and specialized vehicle. The case is made that improved industrial competitiveness requires a large set of mutually consistent national policies including education, tax, saving, fiscal, financial, regulation, inflation, interest, environmental, etc., policies. There does not exist today a mechanism independent of governmental domination, such as a Foundation that provides a viable effective vehicle for the facilitation of public policy in the national interest. HR 4245 would fill this void.

LONG TERM FIT

If the compelling reason for these hearings is to "encourage and support U.S. industrial competitiveness in the international marketplace", I would respectfully suggest that the proposed bills, which have many merits, do not individually nor collectively address the central causes for our loss of competitiveness. This does not mean that the proposed bills are unimportant or impractical. On the contrary, they represent long overdue initiatives that will materially assist U.S. industry. Cooperative, generic development and research will reduce front end costs and accelerate the appearance of products upon the marketplace. The increasing complexity of business along with rapid changes in technology demand access to a broad spectrum of professional competence and specialized technical information that small business simply cannot afford. An industry and professions counterpart of Agriculture Extension would be of immense value to small and medium industry.

I would like to very briefly examine the practical problems created by the current conventional wisdom and societal models before returning to the national policy question.

PARADIGMS AND SOCIETAL MODELS

After W.W.II, the English speaking nations, including the U.S., subscribed to a set of questionable paradigms that distorted national policy while also accepting societal models whose limitations effectively masked crippling structural defects. Let us consider a few of the paradigms and societal models which are important to these hearings.

FALSE PARADIGMS

1. In general and over the long run, leadership in Technological Innovation and Basic Research will insure international trade competitiveness and industrial competence.

   Unfortunately this is not true. Technological innovation, basic research and industrial performance are three entirely different activities with different constituencies, processes and performance criteria. As examples: The U.S. and Britain produced 90% of the research and innovations in liquid crystals while Japan manufactures 90% of the world's liquid crystals. Michael Boretsky pointed out that from 1947 to 1974, the U.S. made seventeen out of eighteen of the major breakthroughs in semiconductor electronics. During the same period of time the U.S. trade balance in electronic and communication equipment (excluding computers) slid from a positive $500 million to a negative $2 billion.

   Corollary: Increased investment in technological innovation and basic research will restore U.S. industrial competitiveness and trade balance.

   The U.S. and Britain already lead the world in basic research as measured by Nobel Science Awards and in innovation as measured by significant patents. The two countries also lead the world in trade deficits. It is difficult to ignore this strong negative correlation and understand how an increase in activities in which we already lead will turn around our long term decline in industrial competence.

2. The "Trickle Down R&D Theory of Science" proclaims: Science leads technology. Industrial competence flows from basic research. If enough money is thrown into scientific research, useful technology will somehow blossom and be deployed successfully.

   The pervasiveness of this inversion of reality is even found in the announcement of these hearings which states:

> "The Federal Government has long done a fine job of encouraging and supporting basic scientific research. But it is becoming increasingly evident that we are much less successful when it comes to transplanting the results of research into useful products and processes. (Underline added.)

The English speaking nations have been pursuing unsuccessfully the R&D illusion (Research leading Development) while our more aggressive trade competitors have been doing D&R. In most of the industrial world, a major societal need or opportunity is first identified, and then a suitable technological development program formulated and funded (i.e., the Fifth Generation Computer.) Only such research is undertaken as is necessary to resolve problems incidental to the development requirements. In other words, Development leads Research (D&R).

Funding of basic research with the expectation that the knowledge generated will somehow provide industrial leadership is an expensive and dangerous way to dissipate the nation's intellectual and financial reserves. Scientific knowledge is an international free good that is readily available for the price of the Journals.

Peter Drucker has written:

> "It is not true that a modern country needs a science base. It can purchase it or import it."

SOCIETAL MODELS

After W.W.II, the U.S. Land Grant tradition, with its emphasis on the professions and cooperation among industry, government, education and the professions, was supplanted by the British Arts-Science tradition with its benign neglect of the professions. In the United States, our leading institutions of higher learning proudly proclaim themselves to be "Research Universities." Rejection of the "three culture" society recognized by most of the world for the limited British Two Cultures model has had the same destructive effects upon the United States' ability to develop and deploy technology as it had upon England. (Reference 4).

POLICY VS PLANNING

It is clear that central national planning is neither acceptable to our people nor capable of practical implementation in a rapidly changing complex modern society. It is equally clear that the government has a vital role in insuring the highest possible life quality for its citizens consistent with the demands of national security. The National life quality in turn is the composite of all environments including the health, education, business, civil, physical, etc., environments. As example, excessive pollution threatens the health of all citizens. Yet, General Motors cannot afford to install emission control devices upon its cars unless Ford must meet the same policy standards.

In the above context, the idea that national policy exists to serve the nation's goals and aspirations is generally accepted. It should be apparent that conflicting national policies, inconsistent policies or the lack of policy, in instances like acid rain, place an expensive and often intolerable burden upon the soeicty. Further, only the very naive would believe that major national policy can stand alone. Successful reindustrialization policies must depend among other things upon tax policies, the intellectual resources and skills derived from our educational policies, the ethical environment policies in which business will operate, and, finally, the policies for long and short term resource allocation between life quality and economic advancement. By itself, pure "Industrial Policy" serving only economic and business needs, is sterile and in practice, counterproductive. Japan found that the early success of its "Industrial Policy" led to substantial degradation of the nation's physical environments and an overcrowding of its major cities.

Consideration of societal paradigms and models, national need and policy requirements, along with the collective functions proposed by the Hearing Bills produces the form and basic assumptions which support a National Policy Facilitating Mechanism.

The National Professions and Technology Foundation, HR 4245, has been based upon the following assumptions:

1. Central Planning is impractical.
2. Technology and Innovation policies should be mutally supporting, consistent parts of the larger national policy structure which in turn, includes life quality policies as well as business and economic policies.
3. The environments - health, education, physical, political, business, civil, etc., which collectively define our society's life quality, are created by the resource allocation, technology deployment and environmental decisions made largely by men and women operating in a public professions capacity.
4. The Federal Government has an unavoidable responsibility for promulgating rational, coherent, self-consistent policy in the national interest.
5. A mechanism, independent of government domination, is necessary to facilitate the creation of the national policies and policy structure required to maintain the competitiveness of U.S. industry in the future.

If the above assumptions are relevant and the Hearing bill functions have validity, the Policy Foundation becomes a reasonable conclusion.

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A NATIONAL POLICY FACILITATING FOUNDATION

Allen B. Rosenstein

Professor of Engineering, UCLA
Chairman, Pioneer Magnetics, Inc.

Conference on Industrial Policy

October 18-19,1983

Loew's L'Enfant Plaza Hotel

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INTRODUCTION

Nearly twenty years ago in the course of a large Ford Foundation study on an entirely different matter, information kept accumulating that led to conclusions sharply contradicting the conventional wisdom of the time. With the U.S. enjoying the world's highest standard of living and possessing a seemingly invincible industrial plant, the data consistently predicted an ever eroding industrial base and a long term decline in the relative quality of life (1). The present national debate over matters such as "Industrial Policy" are the unfortunate consequences of the trends observed in the 60's.

This paper describes a National Policy Facilitating Foundation organized to correct what is undoubtedly the most critical deficiency in America's infrastructure: the lack of a mechanism for facilitating the development of sound and consistent policy in the national welfare including industrial policy.

To provide background for a Policy Foundation and justification for its functions and structure, the extensive decline in America's relative life quality is briefly examined along with three major contributing factors. A set of policy paradigms is offered. Four basic Foundation functions are explored along with supporting structure. Operational analysis shows the Foundation should be created from existing agencies that would bring their operating budgets with them. Significant savings can be effected causing the total direct cost to the government to be less than the presently budgeted agency expenditures.

The paper concludes by describing what we believe will become the overriding national policy issue for the remainder of the century - a problem which has not yet really surfaced, but which will require enormous efforts and great foresight to resolve.

AMERICA'S FUTURE RELATIVE QUALITY OF LIFE

If the trends of the past twenty years foretell America's future, our children will have much less to be thankful for than their parents. Industry provides most of the material goods of our society and generates much of the revenues used to finance our social services. However, by almost any standard, American industry is ill and shows few signs of regaining its ability to compete in world markets. The LICIT report of April 1983 presents a grim picture of world market share trends (2). During the fifteen year period from 1965 to 1980, in twelve major manufacturing catagories ranging from iron and steel to aircraft and computers, France and Japan each increased their percentage of world market share in eight categories. West Germany increased its share in five categories and now leads the U.S (five to four). United States' market share on the other hand declined in ten out of twelve categories. We were saved from last-place performance only by Great Britain, which lost market share in eleven out of twelve categories and remained even in one. The result of our eroding industrial competence is an expected $65,000,000,000 U.S. trade deficit for 1983 and a drop in relative U.S. GNP/capita from first place after W.W.II to tenth place today.

Because of its visibility, we tend to think of our present situation in terms of only one manifestation, the business and industrial environment, and hasten to concentrate on "Industrial Policy" to the exclusion of equally important contributing and interacting factors. National life quality is obviously influenced by the national GNP/capita, but the actual quality of life is given by other environments such as education, health, personal security, pollution, etc. In each of these areas, which are the responsibility of the professions, the U.S. life quality is not outstanding.

Educational test scores have been dropping steadily in the U.S. while functional illiteracy remains at close to 20%. Our ability to allocate our educational resources to effectively serve national needs is questionable. During the past decade, with high technology industry often struggling to satisfy its demand for experienced engineers, California's production of electrical engineers decreased by nearly 30% while the output of lawyers increased 300%. It would almost seem that we plan to litigate our way back to industrial preeminence.

In spite of our enormous investment in medical research and health delivery, Americans are not relatively healthy. It is interesting to note that in 1950, when the National Science Foundation was established, the U.S. ranked sixth in the world in infant mortality. By 1967, the U.S. was winning 50% of the Nobel prizes in Medicine and physiology, but had dropped to 18th place in infant mortality and 21st in longevity. Today the Japanese and the Swedes, with little contribution to medical science, are the world's healthiest people, with the lowest infant mortality rate and the longest life span.

In other life quality areas we are doing no better. Crime is excessive. The average American is more conscious than ever of muggings, burglary and widespread use of narcotics. Our physical environments are still under heavy pressure from pollutants. Acid rain is destroying eastern forests and lakes. Smog levels in our major cities remain high.

HOW DID WE REACH OUR PRESENT STATE?

If our trade with Japan is any indication, the United States is well on its way to becoming a "banana republic." We will supply raw materials - coal, timber and food - to receive in return manufactured goods such as autos, semiconductors, electronic goods, machine tools, etc. Historians seeking to learn why a mighty nation lost its competitive advantage in less than 100 years will find a number of interrelated causes. Each factor by itself has not been sufficient, but together they have throttled the nation's growth. Of the many contributors, three major factors have been particularly devastating:

The first is institutional regidity and structural deficiencies. At a time when our trade partners have developed flexible policy mechanisms allowing them to adjust to ever more dynamic world economic conditions, U.S. institutions have internalized their values and become more rigid. In Washington, government departments "hone" their turf building skills. Problems requiring interdepartmental contributions become even less tractable. Our great universities seek to concentrate upon narrowly defined disciplinary research to the exclusion of real world multidisciplinary problems. At the same time, structural deficiencies insure that national policy questions spanning a number of disciplines and departments cannot be effectively addressed. Mechanisms for anticipating, creating and facilitating flexible, coherent national policy, including industrial policy do not exist.

Secondly, we have made serious educational policy errors. At the end of W.W.II, a major policy shift accelerated through U.S. higher education. The U.S. Land Grant tradition with its emphasis on the professions and cooperation among industry, government, education and the professions, was supplanted by the British arts-science tradition with its benign neglect of the professions. English speaking countries turned their attention with unqualified success to improving their basic research endeavors. As a consequence by the 1970's the U.S. and Britain led the world in two distinct areas: Nobel Science Awards and international trade deficits. Japan and Germany on the other hand contributed little to basic research but led in international trade.

Finally, of all post W.W.II developments, the most dehabilitating change has been the steady movement toward an ever more adversarial society. The United States has adopted the adversarial posture that has failed in Britain, with each sector trying to increase individual return instead of the total good. Industrial productivity has been particularly sensitive to the change. For a seventeen year period beginning with 1960, the average annual percentage productivity increases of the English speaking countries, U.S., Britain and Canada, have been the lowest among the industrial nations. The U.S.at the very bottom averages approximately half the relative productivity improvement of Italy.

The basic problem and the potential solution were contained in trade data observed in 1966. At that time there were some 122 industries - auto, steel, ships, textiles - which employed thirty-five percent of the industrial work force. These industries had formerly dominated world trade but by 1966, were running a $7.5 billion trade deficit. The deficit was of little concern in 1966, for it was masked by the trade surplus created by a handful of U.S. industries such as agriculture, electronics, computers and aircraft. Searching for a pattern to explain the connection between agriculture, computers and aircraft, it finally became clear that prospering industries by and large had enjoyed a long term cooperative partnership of industry, government, university and professions. Declining industries did not. They were characterized by their generally adversarial operation.

THE NEED FOR STRUCTURAL CHANGE

Reich in his book "The Next American Frontier" makes an eloquent case for structural change (3).

> "America has a choice - it can adapt itself to the new economic realities by altering its organizations or it can fail to adapt and thereby continue its present decline ... Adaptation is America's challenge. It is America's next frontier.

> " The myth of the two cultures (business and civic) is retarding the next stage of America's economic and social progress. Adaptation must involve both the business and civic culture, but we have no institutions for bridging the gap and orchestrating adjustment." (Underline added for emphasis.)

The structural gaps and deficiencies in America's basic institutions have come to the attention of many thoughtful citizens. John Kemeny, Chairman of the President's Three Mile Island Commission, after studying the disaster was forced to the conclusion that the fault lay more with obsolescence of our institutions that the reactor operators (4):

> " The present system does not work. It was designed for a much earlier and simpler age.
>
> " The only way to save American democracy is to change the fundamental decision-making process, at the federal level, so it can come to grips with the enormous and complex issues that face the nation."

The Bill being presented has been specifically designed to bridge the adversarial gap and create a cooperative policy facilitating institution.

Congress is not unaware of our rapidly deteriorating trade position and the decline in the national life quality. There are presently nearly 200 bills before the Congress that address segments of the problem or attempt to ameliorate some limited current manifestation of the larger structural deficiencies. The danger lies not in a lack of concern for the national dilemma. But there is the real possibility or even probability that the country will direct so much of its attention and resources to limited, short term "band aid" programs that the larger and more basic long term deficiencies will never be considered. Our country is not facing a small aberation in its economic history. We are at a major crossroad. Institutional changes will be required to turn us away from the present path that we began to travel over twenty years ago. Unfortunately, the institutional roots of our current discomfort had taken hold in the 1950's and were bearing fruit by the mid-1960's. Changing very mature national organizations is never a simple task and indeed can seldom be accomplished except in times of great national stress.

Fortunately, as we shall see, these changes can be made without a major realignment of our basic institutions. We require mostly a reallocation of existing resources into an organization capable of facilitating the critical policy tasks that are not now being addressed.

POLICY PARADIGMS

The new BHI will create a mechanism to facilitate national policy by ensuring representative participation of all responsible sectors of society while avoiding government domination by either business or civic culture. To avoid a current ideological trap, we begin by stating what is not proposed.

What is not proposed

- CENTRAL PLANNING IN ANY FORM OR UNDER ANY GUISE IS NOT CONSIDERED PRACTICAL OR DESIRABLE FOR OUR SOCIETY

  We do not hold that central planning is illegal, unconstitutional or even mildly immoral. The facts dictate that large scale national plans take so long to create and put in place that the dynamics of a modern industrial society render such plans obsolete before they can be implemented. Therefore, central national planning is simply not useful.

  On the other hand, there is mounting evidence that properly supported national policy facilitating mechanisms can achieve the opposite of central planning. The goal is to ensure that every segment of society not only contributes to national policy formulation but that the planning and implementation responsibilities which naturally flow from consistent, rational national policy will be executed by the best qualified sectors of the society itself. With adequate visibility each individual and each business will perceive and implement plans consistent with national policy.

- NONE OF THE POWERS AND RESPONSIBILITIES OF THE LEGISLATIVE OR EXECUTIVE BRANCHES OF THE GOVERNMENT ARE TO BE USURPED OR ASSUMED BY THE NEW ORGANIZATION.

  The institution shall have no legislative or funding authority. Major responsibilities shall be the assessing of existing and emerging national needs and opportunitites, evaluating policy alternatives and presenting the results to the President, Congress and Public for the usual review, modification and funding, when found worthy. Subsequent policy implementation shall be the responsibility of appropriate agencies designated by the Congress.

The Essence of Policy

We assume that the ultimate purpose of a democratic state is to insure the highest possible life quality for its citizens consistent with the demands of national security. In this context, the idea that national policy exists to serve the nation's goals and aspirations is generally accepted.

However, the precise meaning of the words "industrial policy" when taken out of context is not clear for there are many possible combinations of macro, micro and industry specific interventions leading to an almost infinite number of "industrial policies."

In addition to high level macro tax, expenditure, and monetary interventions and the important special cases of foreign and defense policy, an underlying sea of national policies exists that can be organized about the categories of life quality (civic) policies and economic (business) policies somewhat as follows:

Quality of Life

- Housing Policy
- Health Policy
- Education Policy
- Environment Policy
- Public Safety Policy
- Cultural Policy
- Recreation Policy
- Equal Opportunity Policy
- Civil Liberty Policy
- Public Transportation Policy

Economic and Business

- Regulatory Policy
- Trade and Investment Policies
- Enterpreneurship Policy
- Small Business Policy
- Savings Policy
- Finance Policy
- Interest Policy
- Economic Growth Policy
- Energy and Materials Policies
- Public Work Policy
- Infrastructure Policy
- Human Resource and Employment Policies
- Inflation Policy
- R&D Policy

In the real world, neither policy category can stand alone, independent of the other. The resources necessary to maintain the desired national life quality are a direct product of the composite of economic and business policies. At the same time, successful implementation of "industrial" policy must depend among other things upon the intellectual resources and skills derived from our educational policies, the cultural environments in which business will operate and finally the policies for resource allocation between life quality and economic advancement.

By itself, pure "industrial Policy" serving only economic and business needs is sterile and in practice counterproductive. Japan's Ministry of International Trade and Industry (MITI) quickly found that the early successes of its "industrial policy" led to substantial degradation of the nation's physical environments and an overcrowding of its major cities. MITI was forced to add to its policy agencies offices addressing environmental protection, water resources, plant siting, safety, rural development, etc. Indeed, of the three new national goals defined in the Vision of MITI Policies in the 1980's, the first goal is Improved Quality and Comfort of Life and the second is that of Contributing to the International Community. Only the third objective, Overcoming the Limitations of Materials Resources and Energy, would fit the conventional view of "industrial policy."

Regardless of definition, "industrial policy" debates by their very nature are too narrowly focused to be productive. The issue should be opened up to include the full range of interacting, interdependent policies which together seek to secure the national life quality.

Policy vs. Policy Mechanisms

It is our premise that the need to anticipate change and provide timely response require a formal comprehensive policy facilitating mechanism which does not now exist. The present U.S. ad hoc process which has served us so well for nearly two hundred years is too insensitive and cumbersome for national survival. Our eroding industrial base attests to our inability to accommodate the industrial rate of change experienced during the past twenty years and leaves little hope for a future that gives every indication of changing at a still accelerating rate.

A major institutional innovation is required. A given "industrial policy" or policies will not suffice. Indeed, if we were fortunate enough to stumble upon a perfect "industrial policy" or national policy framework, the nation does not have the means to recognize the perfection of these policies, assess the consequences of their wisdom or put together in a timely fashion the national consensus necessary to create the suitable enabling legislation. In other words, we do not have even a rudimentary engine to drive our non existent policy ship.

Further, the dynamics of a modern industrial society guarantee that national policy must continuously change for the society to prosper. International competition is shifting rapidly. The competitive life of many high technology products is less than four years. In 1982, the U.S. General Accounting Office made a study of Japan's impressive growth from a war devastated nation in 1950, to a major economic power today and found (5):

> " Japanese industrial policies have changed significantly over time in response to changes in the international and domestic economy. The flexibility of such policies may, in fact, be the key to the apparent success of industrial policy in Japan."

Specific examples abound of literally overnight shifts in external conditions. The "oil shocks" made major changes in the economics of entire industries including aluminum, shipping, petrochemicals, cement, air transport.

We agree with the G.A.O. report and would only add that policy flexibility requires a policy mechanism to recognize changes in the environments and to modify policy accordingly.

FOUNDATION FUNCTIONS AND STRUCTURE

Turning to the proposed legislation, a successful National Policy Facilitating institution will require: First, a comprehensive high quality information and data base; second, first rate independent capabilities for the analysis of national problems and opportunities and the assessment of policy alternatives; third, highly visible, socially representative mechanisms for achieving national policy consensus; and fourth, the means to facilitate and implement those policies for which there is no presently existing suitable organization.

The world's more aggressive trading countries, Japan, Germany and France, have structured their national policy institutions to perform the preceeding tasks quite well. Describing the Foundation by considering each of its four functions in turn, we shall reference comparable activities from other nations along with one of the oldest and most successful examples of industrial policy - the U.S. Agriculture system.

Policy: Information and Data Base

When the extensive information services of the Government are taken as a whole, it is quite evident that our national data systems are failing on practically every account. J. Peter Grace, Chairman of the President's Private Sector Survey on Cost Control, asserted (6):

> " The whole data processing thing is one big mess. ... the government's 19,300 computers are often incompatible with one another, share no common base of reliable data, use different accounting systems and operate with obsolete technology."

The Technology Task Force of the National Society of Professional Engineers confirmed the inefficiency of our current national data systems, reporting (7) :

> " Each data base has been collected for one purpose without regard for others. They are not accessible from one computer terminal and cannot be pulled together to provide a total picture of what is happening in any one industry on a world-wide basis. Not only are the formats incompatible, the data gathering is often on incompatible time bases or according to mutually incompatible categories of information."

At the national level, proposing policies to influence the future of U.S.industry without benefit of a comprehensive factual foundation would seem foolhardy and irresponsible. Yet in writing about declining industries, Reich observes :

> " No agency of the U.S. government has overall responsibility for gathering detailed information about world market trends, the competitive strategies of trading partners, and the long-term outlook for particular segments and firms with global markets. Instead, the information is gathered piecemeal within the Commerce Department, the State Department, the Treasury, the Internal Revenue Service, the Securities and Exchange commission, the Federal Trade Commission, and other agencies and boards concerned with particular industries, and it is gathered in such broad categories of idiosyncratic detail that it is of little use for making industrial policy. (Underline added.) For example, when the U.S. government was faced with pleas for loan guarantees from the Chrysler Corporation, no government agency was prepared to evaluate Chrysler's position. Congress was forced to rely on a perfunctory study of the industry supplied by a private consulting firm."

To summarize the situation, at a time when the public and private sectors need ready access to high quality, current information, our present policy information systems are far from adequate.

An early task of the Foundation will be to develop and inplement a comprehensive and coherent National Information and Statistics Policy in coordination with existing public and private information agencies. This policy would be directed to the basic direct and indirect factors influencing the national quality of life, including a continuous assessment of U.S. and foreign technology,science, markets, market trends, trade, regulations, customs, tariffs, industry, economy, resources, energy, business, commodities, etc. The objective would be to efficiently provide and make readily available the information and statistics necessary for the more effective functioning of all societal segments and policy makers,including industry, goveroment, labor, academia and the professions.

The public-private information mechanisms of the institution can be best illustrated by a unique American success story. Over 100 years ago the U.S. set in place industrial policy that became a world industrial policy model. A partnership of government, industry and education was created that made the U.S. agriculture industry the world's most efficient generator of food and foreign exchange. At this time, less than 3% of our working force produces over 120% of the nation's food requirements.

Central to the success of U.S. Agriculture is the comprehensive agricultural information system. Data and statistics are drawn from all over the world using every known source including satellites to monitor world food production. The U.S. farmer has ready access to detailed information ranging from world food markets and production, farm management, irrigation, agronomy, biology, plant pathology to the operation of a home garden and the canning of fruit.

Agriculture extension provides classes to educate farmers in the very latest production techniques. If information is not available, the government joins with industry and university to generate needed knowledge in government and university laboratories. The agriculture support system is heavily involved with productivity. Much of California's farm machinery was invented at the University of California. The California Wine Industry owes an enormous debt to the basic work done at the University of California Davis campus.

The government's role in agriculture is very clear. It is to help the agriculture industry.

In contrast to the U.S. neglect of industrial and business information, the Japanese have adapted the U.S. agriculture information system to general industry. The Japanese became concerned in the 1950's about blind trade, i.e., manufacturers operating without detailed information on what they should be producing for various foreign markets. In 1958, the Japan External Trade Organization (JETRO) was established as a public corporation staffed and operated by MITI. With a budget of $66,000,000, JETRO is an information vacuum cleaner sucking up all available international data on an extremely wide spectrum of matters ranging from productivity improvement, national life quality, technical and scientific advances, trade tariffs and economic indicators to local mores and customs.

Foreign information and data is collected, organized and analyzed by JETRO. Similar domestic information is gathered by MITI. Dissemination is provided by a computerized system with powerful software organized to offer data analysis and manipulation for public and private policy creation and decision making. "On line" terminals throughout the country make the data available to all offices of the government, private enterprise and the national policy councils.

Japan's information and statistics system at a fraction of the U.S. expenditure produces substantially more useful product.

Analysis and Assessment.

The long term quality of national life shall be the major concern of the Foundation . To create rational, consistent policy in the national interest requires a deep understanding of the foreign and domestic trade strategies, policies,technologies, etc., that create the environments, physical,business, medical,education, civil, etc. which together determine what we call the quality of national life. Drawing upon the improved national data base the institution will analyze programs and policies to evaluate and assess their present and future impact upon the national life quality,including especially the health of the industrial establishment.

Emerging national opportunities as well as potential national problems would be identified and analyzed. For those areas where a formal policy mechanism does not exist or present policies are inadequate, the Foundation would examine, evaluate, and assess national policy alternatives in the interest of national welfare, the stable development of the economy and the national life quality. In essence, the business of this section of the Foundation shall be the continuous monitoring of the quality of national life, identification of the pending opportunities, needs or unresolved problems that would influence the national welfare, and the formulation where appropriate and assessment of policy alternatives to meet the nation's long term needs including especially the health of the industrial establishment.

A similar function is performed by France's "Commissariat General du Plan" created after W.W.II to meet the conditions for Marshall Plan aid. MITI's Industrial Policy Bureau serves to assess and coordinate industrial policy for Japan.

Pat Chaote has testified (8):

> " ... the key to industrial policy is putting in place a few mechanisms that will facilitate the creation of longer term vision and the translation of that vision into policies and coordinated action."

The juncture between analysis, creation of longer term vision and translation into policies must always be of public concern. To insure a proper transition, we look to the third function of the Foundation - the Search for Consensus.

The Search for Consensus.

Respected, prestigious independent standing National Councils would be created to effectively bridge the interface between vision and policy and provide a viable public policy process that addresses the nation's longer term aspirations.

Independent Councils appointed to cover the full range of social and industrial policy and policy structure are central to the policy process. Acting upon their own initiative or upon policy questions posed by the President, the Congress or the Foundation, the Councils would insure that public opinion involving a broad cross section of the public has been carefully integrated into the policy exercise.

The Councils are specifically designed and charged with the responsibility of serving as highly visible public forums for national policy. Council membership would be drawn from outside the Foundation and composed of leaders in concerned industry, labor, experts in the matters deliberated upon, general consumers and experts from a wide spectrum of society including finance, government, education,mass media and the professions.

The Councils will fill a major structural gap in our present institutions. Turning to Reich once again:

> " America and Britain cling to the fiction of a "managed economy" in which government merely applies neutral principles of fiscal and monetary policy. Structural adjustment cannot be a part of this managerial agenda because there is no consensus about the direction adjustment should take and no organizational arena for forging such a consensus. (Underline added.)

The Foundation and Councils provide both the machinery for defining viable policy alternatives and the organizational arenas in which consensus can be forged.

All of our leading trade competitors have well established institutional means for obtaining a consensus. Germany's Stability and Growth Act of 1966 established a tripartite consultation process to obtain consensus among labor, business and government. MITI has thirty-five associated independent Councils with over 200 standing committees that reach every walk of Japanese life.

It has taken over twenty years for the country to achieve its present state of industrial disarray. Recovery will not come overnight and sacrifices will be required to make the necessary adjustments. Reich observes

> " ...we will also need a national bargaining arena for allocating the burdens and benefits of major adjustment strategies. Such an arena would enable the nation to achieve a broad based consensus about adjustment."

In a practical sense, the public debate and consensus available through the Councils will be of substantial value in enabling elected officials to take policy leadership positions that have less danger of getting too far ahead of public opinion.

Policy Implementation and Facilitation

Possessing no legislative or funding authority, Council and Foundation proposals would be submitted to the Congress and President for the usual review, modification and when found worthy - funding and legislative action.

Implementation of any programs created by Foundation policy proposals would be the responsibility of the appropriate agencies designated by the Congress. In practice, implementation of important national policies may languish for lack of an existing governmental agency that will pursue them. For example, many elements of industrial development crucial to our international competitiveness such as integrated circuits have required Defense Department sponsorship since there is no concerned, competent civilian agency.

To fill the policy facilitation gap, the Foundation,when appropriate,would serve to advance the development and applied research required to realize the policies for those areas of national concern not adequately supported by existing departments. Cooperative industry, labor, university,professions and government programs would be encouraged and facilitated. Attention would be given to removing the barriers that prevent early emergence of industry for the future or the orderly retirement or renovation of declining industries.

As an operating laboratory for the Foundation, the National Bureau of Standards would be transferred from Commerce. Closer ties would be created with the country's national laboratories that in many cases have outlived original mandates. Basic technologies common to all or many industries would be addressed. Foundation technological participation would be limited to development and research in areas of national interest where sufficient development cannot be expected from private enterprise alone due to high risk, prohibitive cost, or long lead times. Beyond the R&D programs, commercialization and diffusion of new technology should be handled by the private sector.

Although the federal government now provides substantial support for science and technological support for selected industries such as agriculture, aviation, and commercial fisheries, we presently lack the institutional capacity to focus programs on the competitive performance of our economy as a whole. As a step to remedy these deficiencies, the Foundation will acquire the Centers for Industrial Technology authorized by Public Law 96-40, with responsibility to join the professions, industry and the university in cooperative activities, including generic research of use to many industries. On the matter of government mandated health, safety and environmental regulations, important activities of the centers would be cooperative efforts to ensure that regulations are achievable by developing the basic methodology and technology necessary to establish feasibility.

Advanced nations use a wide range of institutions, laboratories, associations, etc., to facilitate industrial policy. Germany's primary industrial policy instrument is the Ministry of Research and Technology, BMFT. Promotion of innovation and technological development is the responsibility of the Technology Center and the Venture Financing Corporation . BMFT funds, in addition, Trade Associations, Fraunhofer Gesellschaft, with twenty-eight individual research institutions organized on a disciplinary basis to carry out research useful to industry.

MITI has a very broad policy facilitating responsibility that includes trial policies. Policy is implemented through the most appropriate of a number of means. The fifth generation computer program, for example, was established as a not for profit cooperative corporation. On the other hand, many technology policies including the Sunshine (new energy sources) and Moonlight (energy conservation) programs are carried out by MITI's "Agency for Industrial Science and Technology." This agency with a budget of $700,000,000 has sixteen major national laboratories and the National Standards Department.

COST

The economic value of stable national policy is substantial but its calculation is beyond this paper. We have only enough space to briefly examine the incremental cost to the Government of the proposed institution.

The National Policy Facilitating Foundation has been structured to perform four basic functions. Examining each of these in turn, it is apparent that the proposed functions are offered in one form or another by existing government agencies, departments, bureaus, etc., but generally without the national policy orientation and required cooperative partnership of business and government. Of the four foundation functions, the two most expensive by far will be the establishing and maintaining of a reliable policy data base and policy facilitation but these are also the two activities for which the Foundation should be able to actually reduce the net financial burden upon the government.

Policy Data Base

As the world's earliest user of large scale computer information systems, it is not surprising that the U.S. had to break ground both for equipment and data systems. It is also not surprising that with no formal mechanism for national policy facilitation, the nation's data systems are organized to provide limited local answers.

Peter Grace's committee has already made the case for the massive upgrading of government computer equipment and information systems to provide better service at reduced operating costs. Rationalizing the data base to allow interlinking of machines and data will provide the necessary data processing foundation at substantially less cost. Rationalizing our national information requirements, reducing unnecessary duplication and creating the basis for cooperative information sharing, will allow the U.S. to substantially increase its information gathering capability with no financial penalty.

Policy Analysis and Assessment.

Every department of the government and most large agencies are served by their own policy groups. These groups provide policy analysis and assessment in the context of the mission of their host. The availability of a common comprehensive national and international policy data base will obviously improve the effectivity of most local policy agencies and reduce their data acquisition costs. By drawing upon the expertise of existing private-public policy entities and creating cooperative national policy assessment undertakings, the Foundation will be able to keep the additional funds required for national policy analysis and assessment to a reasonable level.

Policy Consensus.

Reich concludes that:

> "... economic progress depends to an unprecedented degree upon collaboration in our workplaces and consensus in our policies."

To the extent that this statement is true, the cost of the Councils will be insignificant compared to the expected economic gains, As the membership of the Councils would be drawn from outside the Foundation, direct council cost will be nominal. These expenses plus staff and facilities will be new costs although to some extent the National Policy Councils will supplant other councils serving more limited objectives.

Policy Implementation and Facilitation.

It is in the policy implementation and facilitation function that the Foundation with its mandate for cooperative public-private partnerships will create savings and a national return far in excess of the government's investment. Industrial advantages will exceed those already realized by our long standing argiculture industry policy. Even a small crack in our present government-business adversarial mold opens up a host of possibilities. Let us look at two.

Cooperative industry, labor, university and government programs would be encouraged with attention given to areas where sufficient technological development cannot be expected from private enterprise due to high risks, long lead times and the sheer magnitude of the investment. Large scale, high risk undertakings of this nature in the past have been financed almost exclusively by the government. With the government taking the initial risk to establish feasibility, cooperative civilian programs will attract early industry participation with contributions of personnel and funds to materially reduce the cost to the government. MITI has found that industry will actively bid for the right to participate in high priority national programs such as the fifth generation computer and the flexible machining center.

As a second example, by changing environmental protection from its current adversarial operation to a more rational undertaking modeled after our agricultural system, large benefits would be immediately realized by industry, government and the general economy. Our handling of auto exhaust emissions stands as a monument to duplication and inefficiency. Typically, a young bureaucrat, without knowledge of the full physiological effects of emissions or the cost/benefit trade-off of an extra 0.1% reduction of emissions would set standards without knowing if they were practical or achievable. Each of the four auto manufacturers would then independently consume their limited development funds to:

- a) investigate basic phenomena;
- b) educate engineers in the problem;
- c) develop generic methodology to satisfy the requirement if it can be satisfied.

It is difficult to conceive of a more wasteful process.

With a Foundation dedicated to cooperation, industrial environmental policy instead would call for joint government, industry and university efforts. The government with industry support would subsidize the investigation of the basic phenomena at the university. The university would not only lay the foundation for resolution of the problem but also in the process, educate young engineers to implement the solutions - and this is quire important. A solution without trained minds for its implementation is useless. Commercialization and distribution of the practical results of the collaboration would, of course, fall to industry.

THE ULTIMATE POLICY ISSUE

Preoccupation with current "Industrial Policy" has prevented us from considering what shall become the consuming issue for the balance of this century. Yet it is this problem that will decide the final life quality of the U.S. for the forseeable future.

There is now in place a major revolution with social and economic consequences equivalent to anything yet experienced by our country. This modern revolution is of such magnitude and so far reaching that permanent industrial changes are mistaken to be temporary. Consequently, there has been little or no attempt to visualize the policy mechanisms required to appropriately deal with phenomena of this magnitude.

The deterioration of one major U.S. industry after another coupled with the very real suffering of the unemployed causes us to naturally seek short term relief. Hungry people and dying industries cannot be ignored. We look to high technology industry and flexible manufacturing as an answer and to protectionism to buy time. But high technology and protectionism are not enough to carry us into the next century.

The problem can be put into perspective by considering two sets of data. For the first: At the end of the last century, 50% of the U.S. working population was engaged in agriculture. By 1940, less than 3% of the working population produced enough food to feed 120% of our entire population. For the second set of data: 50% of U S. workers were employed by manufacturing in 1947. By 1968 manufacturing engaged 27% of our workers and by 1978 only 22% found manufacturing employment. Continuation of this trend would ensure that manufacturing will join agriculture as an important element of the economy that no longer serves as a major source of employment. In view of the modern mobility of technology and capital, let us examine the probability of the trend continuing and the consequences for an industrial nation.

Last year we were in Japan visiting the Fujitsu Fanuc factory, where robots are busy building robots. Fanuc produces approximately $1,000,000 worth of product per employee per year. Statistics vary with industry, but a well run U.S. factory in reasonable production will usually turn out less than $100,000 worth of product per employee per year. Yet the Fanuc plant is only a prototype to prove feasibility. Japan's National Unmanned Factory project in two years is scheduled to bring on line plants where ten technicians will produce the same amount of product as a U.S. factory with 700 employees-a 70 to 1 labor advantage.

The future of manufacturing employment is quite clear. Automation removes much of the comparative advantage of cheap labor, leaving competition to hinge upon other national comparative advantages such as location, market size, transportation, advanced design capability, raw materials, energy, etc. Our trading partners have proven the potential of the unmanned factory.

Manufacturing employment will continue to decline as machines specific to each industry are developed. The clothing industry offers a good example. Japan, through MITI, has allocated $66 million over 8 years for a cooperative industry, labor, and government project to develop the unmanned garment factory. The government of Sweden started an $88 million, five-year project in 1980, to develop an automatic system for sewing trousers. On a more modest scale, the U.S. government is contributing $1 million over a three-year period to the U.S. effort. The same phenomena that we find in the factory is also occurring in the modern office. Clerical personnel and middle management are primarily involved in data processing and routine decision making - functions that readily lend themselves to computerization.

Competitive pressures among the advanced nations guarantee that the unmanning of manufacturing will continue. In July of this year (1983) only 19.5% of our working population was in manufacturing. During the decade from 1968 to 1978, the manufacturing employment percentage decreased at an average rate of 0.47% per year. But for the last five years the rate jumped to 0.66% per year. Continuation of this rate of decline will reduce manufacturing to only 8.3% of the working population by the year 2000. The turn of the century is less than 17 years hence and 8.3% is less than our present unemployment percentage.

The crises of the next century that we should seek to avoid are not the issues of unemployment, displacement and training. These are important but secondary considerations which we will face if we fail to recognize the more fundamental question, namely: what policy mechanisms should be put in place at this time to insure a manufacturing base adequate to maintain our future national life quality? In an open economy with substantial import-export activity, it is axiomatic that the long term national standard of living will be heavily influenced by the volume of export trade and the value added by manufacturing and service.* A continuing negative trade balance must ultimately result either in a reduction in the real costs (usually that of labor) to stimulate exports and/or a reduction in imports.

Over 100 years ago, national industrial policy created a cooperative mechanism involving government, industry, and education that established a high level of productivity and efficiency in the U.S. agribusiness. It was a wise policy, for great natural resources combined with well-educated farm professionals to give the country a substantial comparative advantage in the world agriculture market. Today, agriculture does not offer significant employment, but it does support our economy by providing foreign exchange. Nearly fifty years after the unmanning of agriculture, the process is being repeated for general industry. The country will soon need an enlightened policy mechanism to seek and realize those manufacturing and service pursuits which will provide the comparative trade advantages required to maintain our national life quality.

* International trade in this instance is intended to include export of services such as engineering, management, financial, transportation, etc., as well as commodities.

THREE FORMS OF DEMOCRATIC GOVERNMENT - TIME FOR A CHOICE

Reich identifies only two forms of democratic government, which he calls the business culture and the civic culture. Going back 100 years to the 1880's, he observes:

> " Since the close of America's first frontier the nation's civic culture and business culture have competed for ideological dominance, producing a pendulum like vacillation in America's fundamental loyalties. With each swing of the pendulum, the country has adopted the perspective of one culture at the expense of the other."

The cause of this oscillation between adversarial forms of government is easy to understand. Competitive, free enterprise is an extremely efficient mechanism for production of the goods and services desired by the society. Unfortunately, completely free enterprise by its very nature cannot address the social imperatives also required by society. General Motors cannot install pollution control devices unless Ford must meet the same standards. The excesses, real or imaginary, of unbridled free enterprise inevitably lead to the demand for a regulatory government. But while the regulatory form of democratic government gives full weight to the social imperatives, competition is inhibited, gross inefficiency is tolerated and the society's ability to effectively provide its needed goods and services begins to wane.

Chalmers Johnson in his book "MITI and the Japanese Miracle," documents the same phenomena in another democratic nation (9). Over a number of decades he traces Japan's oscillation between the two adversarial societal extremes of (state-control) government regulation and (self-control) business dominance before reaching the logical and effective third form of democratic government - a cooperative society in which each segment of the society is encouraged and expected to do what it does best. Johnson contends that much of Japan's high speed growth is a consequence of a synthesis of the two adversarial forms into a third, cooperation. The chief advantage of the third form of government-business relationship, that of public-private cooperation, is that it leaves ownership and management in private hands maintaining high levels of competition. At the same time, it affords the state much greater degrees of

social goal-setting than under self-control (business-dominance.)*
U.S. oscillation during the last seven administrations between business-oriented (Republican) and regulatory (Democratic) governments would indicate that the public is seeking an alternative to our increasingly polarized and adversarial forms of government.

Reich subscribes to the same considerations when he writes:

> " Adaptation must involve both the business and civic cultures."

Johnson and Reich have used different terms (civic and state control vs. business and self control) to identify the two adversarial forms of democratic government. Rational self interest must soon seek the third form of democratic, public-private cooperation. The Johnson and Reich books agree that our present institutional structure is flawed - lacking the mechanisms to facilitate cooperative public-private policies. These are the basic objectives guiding our proposal for the creation of a mechanism to facilitate rational consistent policy in the national interest.

FOUNDATION VS. DEPARTMENT

There are no structural reasons why the policy facilitating proposal could not be implemented within an existing government agency such as the Department of Commerce. However, in the U.S., with the present adversarial relationships among the public and private sectors, we could not find experienced Washington hands who believed that the necessary cooperative mode and mutual confidence could be developed in an existing government agency in time to deal with the pressing national problems of the 1980's.

On the other hand, the National Foundations such as the NSF, have been traditionally staffed and directed by their affected and concerned communities. U.S. Foundations, while funded by the government, are perceived by the public as operating in the public interest without business or political domination.

*We note that Japan has adopted for industry the cooperative, cooperational mode that for 100 years has made the U.S. Agribusiness the most efficient in the world.

An institution dedicated to facilitating cooperative National Policy could not be successful unless it enjoyed public confidence and acceptance comparable to that earned by our present Foundations.

WHAT'S IN A NAME?

The environments - health, education, physical, business, political, civil, etc. - which collectively define our society's quality of life are created by the resource allocation, technology deployment and environmental decisions made largely by men and women operating in a publicly recognized professions capacity. Consequently, the quality of national life and the health of its industry is a direct function of the performance of the nation's public professions and their use of technology.

In this context "The National Professions and Technology Foundation" becomes an appropriate title for an institution dedicated to facilitating national policies for the improvement of the environmental, economic and societal well-being of the nation.

CONCLUSIONS

Legislation has been presented that is designed to correct what is undoubtedly the most critical deficiency in America's infrastructure: the lack of a mechanism for facilitating the development of sound and consistent policies pertaining to our national welfare. Much of our present problem stems from the fact that there is no coordinating point to synthesize various national interests in the policy facilitating process. Too many productive segments of our society have been subject to grave disadvantages as a result of this lack of unity in policy.

As a relevant example of this serious void, America's business community has been unfavorably affected in the realm of national and international trade activity. In the National Business context, not only is there a lack of cohesive and rational public policies aimed at supporting the role of business as a cornerstone of our economy but over the years, an adversarial relationship has evolved between business and government. Business institutions operating in this environment have been subject to excessive and costly regulations, unrealistic tax burdens and the lack of incentive for capital expansion or R&D.

In the international environment, similar inequities exist. Multinational companies must contend with a number of hostile governmental systems in the form of heavily biased trade policies of foreign sovereignties. This results in American based multinationals being placed at a competitive disadvantage in significant foreign markets. These trade policies are non-reciprocating and as a result, do not consequentially affect the ability of foreign-based companies from enjoying unencumbered access to U.S. markets with direct impact upon our balance of payments. Other segments of our society are also affected by the lack of a staging area which can assimilate relevant data to help support the foundation of constructive national policies. These would include the professions, education, agriculture, labor, environmental and social groups and government.

In response to the absence of a unified voice, shaped by the many concerns, problems, ambitions and other inputs from elements of consequential importance to our society, legislation is now being introduced to establish an independent National Policy Facilitating Foundation within the executive branch of government.

The Foundation's charter would be to coordinate and align the efforts of the various social and industry groups, labor, government, professions and academia for the purpose of resolving an array of pressing national policy issues with broad societal implications including "industrial policy."

It seems reasonable to expect that only a legislative mandate can bring about the successful formation of a responsible agency for synthesizing national interests in policy development. There are too many conflicting forces in American society to mediate policy among themselves and create the required consensus.

The failure to act in a positive manner to create a national policy facilitating mechanism such as the proposed Foundation will continue to forestall any progress in coming to terms with present adversarial roles of government, business and other productive sectors of our society.

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EXECUTIVE SUMMARY

A NATIONAL POLICY FACILITATING FOUNDATION

TO BE ENTITLED

THE NATIONAL PROFESSIONS AND TECHNOLOGY FOUNDATION

PURPOSE

To provide a nationally acceptable mechanism capable of anticipating national problems and opportunities and developing cooperative public-private efforts among industry, government, labor, academia and the professions to create and facilitate consistent national policies in the national interest necessary to the improvement of the economic, environmental and societal well being of the United States.

FUNCTIONS

1. Collection, organization and dissemination of a comprehensive international and national data base for policy making;
2. Analysis and assessment of national life quality and industrial policy alternatives with attention to future problems and opportunitites;
3. Public review and national policy consensus generation; and
4. Implementation and facilitation of policy legislation that Congress deems cannot be satisfied by existing agencies.

STRUCTURE

1. Data Base for Policy Making

   o THE NATIONAL TECHNICAL INFORMATION SERVICE AND THE PATENT AND TRADEMARK OFFICE:

   Shall have the responsibility to develop in cooperation with other public and private agencies a comprehensive and coherent National Information and Statistics Policy. This policy would be directed to the measures of the basic factors influencing the national life quality, including a continuous assessment of U.S. and foreign technology, industrial policy and strategy, professions delivery systems and design with promotion of greater accessibility and utilization by small and large business, government, labor, academia and the professions. With the Office of Policy, Analysis and Assessment and other public and private agencies a sectorial information gathering and research capability shall be provided to assess and evaluate industrial developments in the U.S., industry-specific economic developments and the industrial policies of our major trading partners to project their potential effect on U.S. industries, trade and employment.

2. Assessment and Analysis of National Life Quality and Industrial Policy Alternatives

   - OFFICE OF POLICY, ANALYSIS AND ASSESSMENT

     The Office would develop societal indicators of the national life quality along with measures of the health of technology. The effect of U.S. and foreign government, industrial, technological and trade policies upon the national life quality would be studied. The likely future impact on America's producers and workers would be evaluated.

     Emerging national problems would be identified and analyzed. For those areas where a formal policy mechanism does not exist or present policies are inadequate, the Office shall propose, assess and evaluate national policies in the interest of national welfare, the stable development of the economy and the national life quality. In essence, the business of the Office shall be a continuous monitoring of the quality of the nation's life, identification of pending needs or unresolved problems that would influence the national welfare and formulation of policies to best resolve these issues and meet the nation's needs.

3. Public Policy Review and Consensus Generation

   - COUNCILS

     Independent advistory Councils to the Directors and Foundation Offices shall be appointed to cover the full range of Foundation responsibilities and to ensure that public opinion involving a wide section of the public has been taken into account in the policy process. The Councils in response to requests from the President, Congress, Directors or on questions raised on their own initiative shall investigate and deliberate on the directions of the long term and basic policies addressed by the Foundation.

     The Councils shall serve as deliberative public national policy forums. Council membership shall be drawn from outside the Foundation and composed of experts in the matters deliberated upon, leaders in concerned industry, labor, general consumers and experts from a wide spectrum of society including education, mass media, finance, government and the professions.

4. Implementation and Facilitation

   - OFFICE OF NATIONAL PROGRAMS

     This office would serve to implement where appropriate the applied research and development required to realize the policies for those areas of national concern not adequately supported by other agencies. Cooperative industry, labor, university, professions and government programs would be encouraged and facilitated. Attention would be given to removing the barriers that prevent the early emergence of industry for the future or the orderly retirement or renovation of declining industries. Basic technologies common to all or many industries would be addressed. Foundation technological participation would be limited to research and development in areas of substantial national interest where sufficient development cannot be expected from private enterprise alone due to high risk or long lead times. Beyond the R&D programs, commercialization and diffusion of new technology should be handled by the private sector.

- OFFICE OF INSTITUTIONAL AND HUMAN RESOURCE DEVELOPMENT

The Office shall collect and analyze information on professional and technological requirements to provide quantitative projections of human resource needs. Training programs, retraining programs, new curricula and educational institutions to meet these needs shall be implemented including encouragement and assistance for minorities and women to enter the professions.

The Centers for Industrial Technology authorized by Public Law 96-40 shall be made a component of the Office with responsibility to join the professions, industry, and the university in cooperative activities including generic research of use to many industries and the training of individuals in professions and technology innovation. Cooperative government, industry, labor, university and professions efforts in the matter of government mandated health, safety and environmental regulation would be important activities of the Centers.

- OFFICE OF SMALL BUSINESS

This office shall materially improve the resources and capabilities of U.S. small business enterprise including upgrading production technology by grants and incentives for cooperative industry wide R&D, promotion of computerization, advancing and modernizing production capability and facilities by training technical, professional, enterpreneurial and managerial personnel and by linking small business with venture capital.

A major undertaking shall be the creation of the professions and technology counterpart of the U.S. agriculture system to provide ready access by individual companies and industry to advice, support and expert consultation upon (but not limited to) the latest manufacturing processes, management systems, quality assurance methods, production techniques, personnel procedures, computer applications, financial controls and extension services. These programs would be in cooperation with the Centers for Industrial Technology. Other functions would be to foster communications between technological and scientific agencies of the Federal government and the small business community, assist high-technology small businesses in dealing with the Federal government and recommend policies enabling the nation to benefit more from high technology small business.

- OFFICE OF THE PROFESSIONS

This office would support by extramural grants and contracts fundamental research in the engineering disciplines and nationally needed applied research in all professions not adequately supported from other sources.

Mechanisms shall be investigated to facilitate the implementation of cooperative public and private undertakings in the national interest to replace the present adversarial relationship. Techniques and means for applying risk analysis and decision theory to Federal Agency regulation formation and resource allocation shall be studied and implemented where feasible.

- OFFICE OF INTERGOVERNMENTAL TECHNOLOGY AND PROFESSIONS DELIVERY SYSTEMS

  State and local governments exist almost exclusively for the delivery of services offered by the public professions. The Office would facilitate the integration of the latest professions delivery systems and technological resources into the policy formulation, delivery systems management and program operation of state and local governments. Cooperation would be supported and facilitated between government (state and local) and the university to make the resources of the university's professional schools available to legislators for the regular assessment and evaluation of policy questions, programs and issues on a multi-professional basis.

- THE NATIONAL BUREAU OF STANDARDS

  In addition to the Bureau's present duties and where appropriate, mechanisms shall be developed to foster public-private partnerships involving the Bureau and the national laboratories in the applied R&D often required for implementation of specific industrial policies in the national interest.

COSTS

Although the Foundation will have a large budget, very little new money will be required as the agencies transferred to the Foundation will bring their current operating budgets with them. For example, the Bureau of Standards has a 1983 budget of $100,456,000.

Examining the four functions of the Foundation, modest amounts of additional funding will be required for the Councils and for Policy, Analysis and Assessment. These costs will be more than offset by the efficiencies to be realized by rationalizing the nation's information and data processing systems along with the government-industry savings that will accrue from cooperative policy facilitating R&D ventures.

FOUNDATION TITLE

The environments - health, education, physical, business, political, civil, etc. - which collectively define our society's quality of life are created by the resource allocation, technology deployment and environmental decisions made largely by men and women operating in a publicly recognized professions capacity. Consequently, the quality of national life and the health of its industry is a direct function of the performance of the nation's public professions and their use of technology.

In this context "The National Professions and Technology Foundation" becomes an appropriate title for an institution dedicated to facilitating national policies for the improvement of the environmental, economic and societal well-being of the nation.

DEPARTMENT VS. FOUNDATION

There are no structural reasons why the proposal could not be implemented within an existing government department such as the Department of Commerce. However, in the U.S. with the present adversarial relationship among the public and private sectors, it does not seem practical to expect that the necessary cooperative mode and mutual confidence can be developed in an existing government agency in time to deal with the pressing national problems of the 1980's.

On the other hand, the National Foundations such as the NSF have been traditionally staffed and directed by their affected and concerned communities. U.S. Foundations, while funded by the government, are perceived by the public as operating in the public interest without government or political domination. An institution dedicated to facilitating cooperative National Policy cannot be successful unless it enjoys public confidence and acceptance comparable to that earned by our present foundations.

WHAT IS NOT PROPOSED

- CENTRAL PLANNING IN ANY FORM OR UNDER ANY GUISE IS NOT CONSIDERED PRACTICAL OR DESIREABLE FOR OUR SOCIETY.

  We do not hold that central planning is illegal, unconstitutional or even mildly immoral. The facts dictate that large scale national plans take so long to create and put in place that the dynamics of a modern industrial society render such plans obsolete before they can be implemented. Therefore, central national planning is simply not useful.

  On the other hand, there is mounting evidence that properly supported national policy facilitating mechanisms can achieve the opposite of central planning. The goal is to ensure that every segment of society not only contributes to national policyformulation but that the planning and implementation responsibilities which naturally flow from consistent, rational national policy will be executed by the best qualified sectors of the society itself. With adequate visibility each individual and each business will perceive and implement plans consistent with national policy.

- NONE OF THE POWERS AND RESPONSIBILITIES OF THE LEGISLATIVE OR EXECUTIVE BRANCHES OF THE GOVERNMENT ARE TO BE USURPED OR ASSUMED BY THE NEW ORGANIZATION

  The institution shall have no legislative or funding authority. Major responsibilities shall be the assessing of existing and emerging national needs, evaluating policy alternatives and presenting the results to the President, Congress and Public for the usual review, modification and funding, when found worthy. Subsequent program implementation shall be the responsibility of appropriate agencies designated by the Congress.

H.R. 4245

A NATIONAL POLICY FACILITATING FOUNDATION

TO BE ENTITLED

THE NATIONAL PROFESSIONS AND TECHNOLOGY FOUNDATION

ENCLOSURE "B"

H.R. 4245

NATIONAL PROFESSIONS & TECHNOLOGY FOUNDATION

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I

REFERENCE I.

98TH CONGRESS
1ST SESSION

H. R. 4245

To advance the national prosperity, quality of life, and welfare, to establish a National Professions and Technology Foundation, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

OCTOBER 28, 1983

Mr. BROWN of California (for himself, Mr. WALGREN, Mr. LUNDINE, Mr. DYMALLY, Mr. UDALL, Mr. WAXMAN, Mr. EDGAR, Mrs. SCHROEDER, Mr. HAWKINS, Mr. BEILENSON, Mr. BERMAN, Mr. TORRES, and Mr. LEVINE of California) introduced the following bill; which was referred jointly to the Committees on Science and Technology and the Judiciary

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A BILL

To advance the national prosperity, quality of life, and welfare, to establish a National Professions and Technology Foundation, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SHORT TITLE

SECTION 1. This Act may be cited as the "National Professions and Technology Foundation Act of 1983".

FINDINGS

SEC. 2. The Congress finds and declares that—

(a) SOCIETAL ROLES.—Adversarial vs Cooperative.—

(1) Ours is a hybrid society, part free enterprise, part government controlled, with an increasing need for a cooperative partnership of government, business, university, labor and the professions in the public interest with each sector making its appropriate contribution.

(2) Confusion of the roles of government, the private sector, university, labor and the professions has contributed to the creation of an adversarial society, often with undercooperation and excessive regulation.

(3) Other developed nations generally have closer government, industry, education and professions cooperation than does the United States, particularly in the foreign trade arena. With the increasingly global trade patterns that accompany world development and the penetration of United States markets by foreign competitors, the United States will have to provide for closer government, industry, labor, education, and professions cooperation in order to compete successfully.

(4) To ensure a healthy national society and economy there is a need to forge closer links among sectors of society in the arena of technology and the professions, improved links among government, industry, labor, academia and the professions are essential. Many new discoveries and advances in theory and practice

occur in universities and government laboratories, while dissemination and utilization of these advances for commercial and useful public purposes depends largely upon actions by business, labor and other parts of government.

(5) Adversarial societies, with government, industry, labor, education and the professions each trying to maximize individual returns instead of the total quality of life have proven to be less effective than societies which encourage a cooperative partnership of these basic elements. Strong industries in the United States such as agriculture, computers, aircraft, semiconductors, have benefitted from a healthy partnership of government, industry, education, and the professions. Declining industries on the other hand—automobile, steel, consumer electronics—are largely characterized by a long standing adversarial relationship.

(6) The performance of both the National Science Foundation, which is managed by the country's science community, and the agriculture extension system that draws upon education and the farm industry, demonstrate that cooperative mechanisms can be created in the national interest which will not be dominated by the Federal Government or exercise excessive government control. In these areas, government provides in-

centives and long-term support while policy, direction, and operation comes from the society, Japan's MITI and the United States agriculture system are models of cooperative action in the national interest without government domination.

(b) ANALYSIS AND ASSESSMENT.—

(1) There is a need to arrange for objective tradeoff analyses to balance out public benefits versus risks in our policy selection process. United States public institutions are not properly organized to weigh our modern technological society's options, compare the benefits and disbenefits and then execute timely balanced national policies.

(2) There presently are no adequate means to measure the quality of life in the Nation or to predict the impact upon the Nation of new developments in education, medicine, science, business, law, technology, social institutions, and other areas.

(c) POLICY AND CHANGE.—

(1) As a nation we need a highly visible, public process to formulate, evaluate and institute national policy alternatives. In turn, means are required to more effectively change our institutions so they may better serve national policies and anticipate new demands.

(2) There is a maturing need to propose, debate and refine national policies to serve the public welfare for interdependent areas of common interest such as international trade, industrial policy, technology, the economy, savings, R&D, technological and professional innovation, productivity, human resources, institutional development, etc.

(3) With increasing frequency, national leaders point to our lack of national policies and the absence of a mechanism to anticipate the national policies and priorities needed to prevent the country from staggering from one crisis to another.

(4) Although there does not now exist in the United States a nationally accepted mechanism for assessing long term national needs and proposing and evaluating comprehensive, integrated sets of policies in the national interest, other leading modern nations have successfully developed policy proposing institutions. Japan's Ministry of International Trade and Industry (MITI) is an outstanding example.

(5) Successful national policy implementation requires an integrated, mutually supporting set of policies. As an example Japan's national trade and industry policy has required the development of a national design policy and a national financial policy. The

design policy has been supported by a national information policy and a national educational policy. (Japan produces twice as many engineers as the United States.) The national financial policy allows Japanese industry to borrow at a 9.3 percent interest rate versus the current United States average of 17.3 percent. The financial policy is buttressed by a national saving policy which gives tax incentives that cause the Japanese to save 20 percent of their disposable income compared to the 6.5 percent for the United States.

(6) Success in international trade competition is more dependent upon national economic, financial, saving, education, and information policies than upon technical innovation. The latest production equipment, production methods and scientific knowledge can be imported at small cost.

(7) Goverment policies in area such as antitrust, economics, information gathering and distribution, labor, trade, patents, procurement, regulation, research and development, small businesses, and taxes have significant impact upon the national life quality including professional innovation and development of technology, but there is insufficient knowledge of their effects upon the Nation.

(8) No significant guidance is presently being given to the manner in which the public professions affect the quality of life in the Nation and there are no major programs or policies designed to involve the public professions in a coordinated effort to resolve the national problems or to enable the public professions to more effectively discharge their societal responsibilities.

(d) HUMAN RESOURCES.—

(1) The Nation has not given adequate attention to its long term requirements for professional, scientific and technical personnel.

(2) The United States has no comprehensive policy or commitment to nsure adequate supplies of properly educated professionals, scientists, and technicians for emerging fields important for the national welfare.

(3) Underutilization of women and minorities in the Nation's professions represent a significant loss of intellectual resources that is not in the national interest.

(e) INSTITUTIONAL NEEDS.—

(1) Emerging national problems frequently receive inadequate attention in the executive branch of the Federal Government because existing agencies have existing missions and little incentive to extend them-

selves beyond those missions. An agency charged with identifying emerging national problems, studying them, and developing programs to address them is needed.

(2) It has proven impractical for the National Science Foundation with its responsibility for basic research to also effectively discharge the national problem solving, resource allocation, and quality of life responsibilities of the public professions.

(f) THE PROFESSIONS.—

(1) The problems of the Nation are characterized by their demand for multiprofessional solutions.

(2) It is in the nature of societal advancement, i.e., improvement of the many environments that provide the national life quality, that most fields of endeavor require assembling interdisciplinary-multiprofessional talents, involving a combination of knowledge and experience in various fields. A systems solution of a problem or need will win out over segmental attacks.

(3) The public professions, acting in a coordinated manner, can make important contributions to the solution of national problems.

(4) The collective expertise of the public professions is capable of providing methods for measuring, projecting and improving the quality of life in the Nation.

(g) TECHNOLOGY AND TRADE.—

(1) The international balance of trade has been unfavorable to the United States for several years, including unfavorable balances in some industries heavily dependent upon technology.

(2) High-technology industries have been responsible for the creation of a higher share of new jobs than low-technology industries, and the development of new technologies promises fuller national employment.

(3) The development of a new technology either offers new goods or services for the national welfare or provides existing goods and services at lower costs. Thus, new technologies are generally counterinflationary, improve the national balance of trade, and support the United States dollar in international monetary exchange.

(h) SMALL BUSINESS.—The potential of small business for technological innovation and the creation of new jobs is great but has been inadequately realized, largely through the inattention of government.

(i) INFORMATION RESOURCES.—Half or more of the good ideas in technology, the professions and science will originate outside the United States. Our ability to utilize these ideas to our advantage will depend to a great extent on our alertness and ability to bring in, adapt to our needs, and disseminate the advances that start outside our boundaries.

(j) PRODUCTIVITY, INNOVATION AND THE FUTURE.—

(1) The productivity and rate of innovation of many national industries are lagging compared with historical pattern and with the performance of the same industries in other nations, and are not sufficient to provide for a healthy economy.

(2) Our institutions and industry face a future of rapid change and increasing complexity, with success dependent upon knowledge intensification and energy conservation. Intelligent machines and robotics will call for considerably fewer workers but with much higher skills. At the same time, there will be a substantial increase in the average age of the population.

(k) DESIGN.—

(1) The increasing complexity of human needs, depletion of national resources, and expanding population placing an increased burden upon the environments, and the rapid development of technology makes excellence in design of products and systems a necessity.

(2) The increased demand for United States products and systems resulting from the promotion of excellence in design will stimulate expansion of the Nation's

trade and will result in increased employment opportunities for United States citizens.

PURPOSE

SEC. 3. It is the purpose of the Congress in this Act to establish a National Professions and Technology Foundation which shall develop coordinated efforts among the public professions, industry, labor, government, and academia for the resolution of national problems and the identification of national opportunities on a multiprofessional, multidisciplinary basis and shall promote the advance of technology, professional innovation and the supply of professional and technical manpower for the improvement of the economic, environmental, and societal well-being of the United States, including development of the requisite knowledge base, promotion of standards and the long-range analysis, assessment and policies needed for each of these areas.

DEFINITIONS

SEC. 4. As used in this Act, the term—

(1) "Foundation" means the National Professions and Technology Foundation established by this Act;

(2) "Director" means the Director of the National Professions and Technology Foundation;

(3) "Board" means the National Professions and Technology Board established by this Act;

(4) "technology" means not only machinery, electronics, tools, chemicals, etc., but ideas which advance human capabilities, and also the structure and management of the human organization of our society;

(5) "public profession" means a body of persons engaged in a calling which requires specialized knowledge, which may require extensive educational preparation, which has a significant relationship with public affairs and the allocation of national resources, which is accountable to constituencies and the public, and which includes but is not limited to accounting, architecture, criminology, dentistry, education, continuing education, engineering, finance, journalism, law, management, medicine, mental health, nursing, pharmacy, public administration and legislation, public health, social welfare and urban planning;

(6) "institution of higher education" means a college, university or school in any State or foreign country which—

(A) admits as regular students only individuals having a certificate of graduation from a school providing secondary education or the recognized equivalent of such certificate;

(B) is legally authorized within such State or foreign country to provide a program of education beyond secondary education;

(C) provides an educational program for which it awards a bachelor's degree or other degree, or provides not less than a two-year program which is acceptable for full credit toward a bachelor's degree;

(D) is a public or other nonprofit institution;

(E) is accredited by an accrediting organization or association determined by the Foundation to be a reliable authority as to the quality of training offered.

(7) "agency" means any Federal executive agency; and

(8) "State" means the several States, the District of Columbia, the Commonwealth of Puerto Rico, the Trust Territory of the Pacific Islands, or any other territory or possession of the United States.

ESTABLISHMENT OF THE NATIONAL PROFESSIONS AND TECHNOLOGY FOUNDATION

SEC. 5. (a) There is hereby established in the executive branch of the Federal Government an independent agency to be known as the National Professions and Technology Foundation.

(b) There are hereby established in the Foundation—

(1) a National Professions and Technology Board, to function in accordance with section 7;

(2) an Office of Director of the Foundation, to function in accordance with section 8;

(3) an Office of National Policy, Analysis and Assessment;

(4) an Office of National Programs;

(5) an Office of the Professions;

(6) an Office of Human Resources;

(7) an Office of Small Business; and

(8) an Office of Intergovernmental Technology and Professions Delivery Systems.

(c) There are hereby transferred to the Foundation—

(1) the National Bureau of Standards of the Department of Commerce;

(2) the Patent and Trademark Office of the Department of Commerce;

(3) the National Technical Information Service of the Department of Commerce;

(4) the Office of Small Business Research and Development of the National Science Foundation;

(5) the Directorate for Engineering of the National Science Foundation;

(6) the Division of Industrial Science and Technological Innovation (exclusive of the nonengineering programs of the industry/university cooperative research projects program element) of the National Science Foundation;

(7) the Intergovernmental Programs Section of the National Science Foundation;

(8) the Office of Industrial Technology of the Department of Commerce (as established under section 5 of the Stevenson-Wydler Technology Innovation Act of 1980); and

(9) the Center for the Utilization of Federal Technology of the Department of Commerce (as established by section 11(d) of such Act).

(d) There are hereby transferred to the Foundation all the functions, powers, duties, and authorities of the National Science Foundation and the Secretary of Commerce under the Stevenson-Wydler Technology Innovation Act of 1980.

FUNCTIONS OF THE NATIONAL PROFESSIONS AND TECHNOLOGY FOUNDATION

SEC. 6. (a) The Foundation shall, through the National Office of Policy, Analysis and Assessment—

(1) in cooperation with the professional societies and the statistical agencies of the Federal Government, develop improved indicators of the quality of national

life along with those activities such as measures of innovation and productivity which contribute to the national well-being;

(2) conduct analyses and assessments, including studies of the effects of technology and the professions upon the past, present, and future quality of national life;

(3) determine the influence of economic conditions, professions programs, higher education structure and policy, labor conditions, industrial structure and management, and government programs and policies on industrial and professional innovation, the development and utilization of technology and the national quality of life;

(4) develop methods to assess existing and proposed programs and policies of the public professions with a view toward—

(A) forecasting the impact of such programs and policies upon the quality of life in the Nation; and

(B) suggesting, whenever necessary, alternative programs, policies, and resources to attain improved quality of life.

(5) determine the relationships of technological and professional developments and international tech-

nology transfers to the output, employment, productivity and world trade performance of the United States and Foreign industrial sectors;

(6) identify technological and professional needs, problems and opportunities within and across industrial sectors that, if addressed, could make a significant contribution to the economy of the United States;

(7) assess whether the capital, human, technical, and other resources being allocated to domestic industrial sectors which are likely to generate new technologies are adequate to meet private and social demands for goods and services and to promote productivity and economic growth;

(8) conduct, either directly or through grants, loans and other assistance, studies and evaluations of the operation of the public professions, the delivery of services by the public professions and the manner in which governmental agencies use the services of public professions;

(9) develop and encourage the pursuit of a broadly conceived national professions policy, which supports the national interest and a plan for periodic updating of such policy;

(10) propose and support studies and policy experiments in cooperation with other Federal agencies,

to determine the effectiveness of measures, with the potential of advancing United States technological and professions innovations;

(11) recommend to the Director, for transmission to the President and Congress, government measures with the potential of advancing United States technological and professions innovation and exploiting innovations of foreign origin;

(12) cooperate and coordinate with other policy bodies of the Federal, State, and local governments;

(13) propose, assess and evaluate national policies in the interest of the national welfare, stable development of the economy and quality of life for those areas where a formal policy mechanism does not exist or present policies are inadequate;

(14) propose policies to actively promote cooperative rather than adversarial public and private sector relations and policy development;

(15) formulate for national review, debate and implementation long range industrial policies with attention given to:

(A) industries of the future whose early implementation will affect the national prosperity and life quality;

(B) identification and promotion of the basic technology and R&D necessary to support the next generation of new industry;

(C) development of basic fields common to all industries such as new materials and biotechnology;

(D) mechanisms for promotion and support of long term industry, labor, university, professions and government partnerships, including the national laboratories;

(E) areas where government aid should be considered when sufficient technological development cannot be expected from private enterprise due to high risks, long lead times, and the sheer magnitude of the investment. In principle, government support should be given only to research and development programs with commercialization and new technology diffusion the responsibility of individual companies;

(F) tax, financial, savings and investment incentives;

(G) declining and troubled industries with significant impact upon the national economy or local regions;

(H) industrial structure, organization, location and environmental impact;

(I) innovation and productivity;

(J) the promotion of standardization;

(K) maximizing the ability and effectiveness of private enterprise, including cooperative and not-for-profit institutions;

(L) encouragement of private technology development efforts, including subsidies where appropriate to stimulate the development of critical technology;

(16) in cooperation with the Office of National Programs establish a coordinated multiprofessions effort with full participations of industry, labor, education, and the appropriate Foundation Councils to—

(A) identify emerging national problems and needs including those of industry, technology and the professions that are not adequately resolved by other public and private institutions;

(B) propose policies and programs to properly resolve such problems and needs; and

(C) present at regular intervals of not more than ten years an emerging problems and opportunities analysis for national review and comment to develop a vision of the succeeding decade; the analysis should be part of an ongoing and systematic critical trends assessment program;

(17) in cooperation with the Office of Human Resources develop long-term National Professional and Technological human resource policies to guide where private and Federal funds would be best employed to insure the Nation's well-being;

(18) establish in cooperation with the Office of Science and Technology Policy and the National Endowment for the Humanities a program for improving the use of risk analysis and decision theory and other forcasting methods by Federal agencies concerned with regulatory decisions and national resource allocation;

(19) in cooperation with the Office of Small Business, develop policies and programs to materially improve the resources and capabilities of United States small enterprise;

(20) in cooperation with the National Technical Information Service, develop and propose for national review and implementation a coherent, comprehensive National Information Policy; and

(21) in cooperation with other offices and with the advice and recommendations of the Foundation's Councils, the Office shall at intervals of not more than ten years provide a comprehensive analysis and evaluation

of the functioning of the Foundation, its effectivity in anticipating and meeting national problems, including a comparative analysis with similar institutions in other countries, and then submit to the Congress a plan for Foundation renewal or termination.

(b) The Foundation shall, through the Office of National Programs—

(1) in cooperation with the National Office of Policy, Analysis and Assessment, identify emerging national problems, opportunities, and needs including those of industry, technology, and the professions that cannot be adequately satisfied by other public and private institutions;

(2) establish coordinated multiprofessions efforts with full participation of industry, government, labor, educators and representatives of public interest groups to—

(A) determine approaches, resources and priorities required to implement the policies and programs of paragraph (1) and encourage and facilitate cooperative government, industry, labor, education and professions programs, applied research and the development of solutions either through the National Bureau of Standards, the National

Laboratories or by extramural grants and contacts to the universities and industry;

(B) address issues common to all industries including pollution and location;

(3) support such extramural applied research and development as falls outside the purview of other Federal agencies and should be supported in the national interest;

(4) carry out the problem focussed programs other than intergovernmental programs, centers programs, engineering programs, and small business programs transferred to the Foundation by section 5(c)(5) of this Act;

(5) identify declining or less competitive industries important to the national welfare and cooperate with the Department of Commerce to develop and implement national and regional plans and policies for these industries.

(c) The Foundation shall, through the Office of the Professions—

(1) carry out engineering programs transferred to the Foundation by section 5(c)(5) of this Act, including the establishment of an Engineering Directorate within the Office;

(2) support applied research and development in engineering disciplines not adequately supported by other sources of funding, and support fundamental research in all engineering disciplines;

(3) support applied research and development in disciplines of the professions not adequately supported by other sources of funding;

(4) establish, through grants, loans and other assistance, programs of investigation and applied research among the public professions designed to understand and facilitate the mechanisms necessary to involve the public professions in partnership with industry, labor, education, and government for the solution of national problems; and further, where appropriate, closer cooperation with local, State, and Federal agencies;

(5) provide for seminars, conferences and lectures designed to promote public and professional understanding of the public resource allocating and environmental decisionmaking role of the professions and the need for cooperation among government, industry, university, labor and the professions to counteract the present unproductive adversarial relationships;

(6) act as a clearinghouse of information with respect to the public professions and the need for services offered by the public professions;

(7) establish programs of exchange between the public professions in the United States and other countries; and

(8) develop and implement a program of applied research and development directed at strengthening the knowledge base and methodology required to support government agencies in utilizing risk analysis, decision theory, and other forecasting methods in regulatory and resource allocation decisionmaking including cooperative applied research to be undertaken with the Endowment for the Humanities to develop methodology for the determination of socially acceptable risks and value systems.

(d)(1) The Foundation shall, through the Office of Human Resources—

(A) in cooperation with the Office of Policy, Analysis and Assessment, develop and maintain long term national professional and technological human resource policies to guide where private and Federal funds would be best employed to insure the Nation's well being including:

(i) establishment of a national council on professional, technical and scientific manpower;

(ii) establishing and maintaining the necessary means for identifying and assessing the short and long term professions, technical and scientific human resource needs necessary for the well being of the Nation and to provide policies and programs necessary to meet these needs (including such resources as personnel, institutions, equipment, facilities and funding);

(iii) assisting in the preparation of such long range technical human resource assessments and policy recommendations as are required or authorized by the National Science and Technology Policy, Organization and Priorities Act of 1976 (42 U.S.C. 6601 et seq.);

(B) encourage and support public professions and technical training and educational institutions which may include, but need not be limited to—

(i) establishing, operating or providing funding for training or educational institutions, including libraries;

(ii) providing grants, loans, or other assistance to individuals;

(iii) developing professions curricula or training programs in anticipation of national needs; and

(iv) encouraging and providing assistance for minorities and women to enter the professions;

(C) encourage the temporary exchange of professional personnel between academia and industry to promote the purpose of this Act as set forth in section 3; and

(D) carry out the functions, powers, duties and responsibilities transferred by section 5(d) of this Act with respect to providing assistance for the establishment of Centers for Industrial Technology and Design and the programs of such Centers transferred by sections 5(c)(6) and 5(c)(8) of this Act, to enhance technological and professional innovation through—

(i) the participation of individuals from industry, professions, and universities in cooperative technology and professions innovation activities;

(ii) the identification and development of the generic knowledge, technology and/or methodolgy base important for technological advances in the quality of life and innovative activity in which individual firms have little incentive to invest, but which may have significant economic importance, such as a manufacturing technology or a pollution control system;

(iii) facilitate cooperative government, industry, labor, university, and professions efforts in the matter of government mandated health, safety, and environment regulations.

(I) to ensure that the regulations are achievable;

(II) to develop the basic methodology and technology for satisfying the regulations and minimizing costs of duplicative research;

(III) to educate professionals in the required technology;

(IV) to apply comparative risk analysis, decision theory, and other forecasting methodologies to regulation formulation to ensure a societal return comparable to the societal investment; and

(V) to encourage innovation in satisfying regulations.

(iv) the education and training of individuals in professional and technology innovation;

(v) the improvement of mechanisms in the dissemination of scientific professional and technical information between universities, industry, and the professions.

(vi) the utilization of the capability and expertise where appropriate, that exists in Federal laboratories; and

(vii) the development of continuing financial support from industry and universities through, among other means, fees, licenses and royalties.

(2) The activities of the Centers established pursuant to paragraph (1)(D) of this section may include, but need not be limited to—

(A) research supportive of technology, professions, and industrial innovation including cooperative industry, professions, and university basic and applied research;

(B) assistance in the evaluation and development of technological ideas supportive of industrial innovation and new business ventures;

(C) technological and professional assistance and advisory services to industry (including cooperative and non-profit organizations), government, and the professions;

(D) curriculum development and instruction in invention, entrepreneurship, and professional innovation and multiprofessional problem resolution.

(3) Prior to establishing a Center pursuant to paragraph (1) the Director shall find that—

(A) consideration has been given to the potential contribution to productivity, employment, and economic competitiveness and national life quality of the United States of the activities proposed under the Center;

(B) a high likelihood exists of continuing participation, advice, financial support, and other contributions from the private sector, including industry, labor and the professions.

(C) the host university or nonprofit institution has a plan for the management and evaluation of the activities proposed within the particular Center, including consideration of means to place the Center, to the maximum extent feasible, on a self-sustaining basis; and

(D) suitable consideration has been given to the proposed geographical location of the Center.

(e) The Foundation shall, through the Office of Small Business—

(1) in cooperation with the Office of Policy, Analysis and Assessment, develop and implement policies and programs to materially improve the resources and capabilities of United States small enterprise including but not limited to:

(A) upgrading the production technology available to small enterprise through grants and incentives for research and development projects including those conducted jointly by industry, universities and public and private research organizations.

(B) training technical, professional, entrepreneurial and management personnel;

(C) promotion of computerization in small enterprise for design, manufacture and management;

(D) advancing and modernizing production capabilities and facilities; and

(E) providing management consultation.

(2) in cooperation with the Office of Human Resources create the professions and technology counterpart of the United States Agriculture Extension System to provide access by individual company and industry to advise, support and expert consultation, including but not limited to: the latest manufacturing processes, management systems, quality assurance methods, production techniques, personnel procedures, computer applications, financial controls, and extension services;

(3) operate programs of grants and contracts for the development and advancement of high-technology

small businesses including joint cooperative industry, education, government, applied research and development;

(4) foster communication between scientific and technological agencies of the Federal Government and the small business community;

(5) collect, analyze, compile, and publish information concerning grants and contracts awarded to small business concerns by scientific and technical agencies of the Federal Government, and the procedures for handling proposals submitted by small business concerns;

(6) assist individual high-technology small business concerns in obtaining information regarding programs, policies, regulations and procedures of the Federal Government, and assist such businesses in dealing with the Federal Government;

(7) recommend to the Director for transmission to the President such changes in the laws, procedures, policies and practices of the Federal Government as may be required to enable the Nation to benefit more fully from the resources of high-technology small businesses; and

(8) carry out the programs of the agencies transferred by section 5(c)(4) and small business program of the agencies transferred by section 5(c)(6).

(f) The Foundation shall, through the Office of Intergovernmental Technology and Professions Delivery Systems:

(1) provide staff support for the President's Intergovernmental Science, Engineering and Technology Advisory Panel;

(2) carry out the intergovernmental programs transferred to the Foundation through section 5(c)(7) of this Act;

(3) facilitate the integration of professional, scientific and technological resources into the policy formation, management support and program operation activities of State and local governments;

(4) promote technology transfer from the Federal Government and private enterprise to State and local governments;

(5) support and promote the appropriate utilization of technology through organized State or local programs of technology and technology information distribution;

(6) carry out the programs transferred to the Foundation by section 5(c)(9) of this Act;

(7) study and improve the delivery of services by the professions and the performance of professions delivery systems in government; and

(8) support and facilitate cooperation between government (national, State, county, and city) and the professional schools of the university to make the resources of the university available to legislators for the regular assessment and evaluation of policies, problems, programs, and issues on a multiprofessional systems basis.

(g) The Foundation shall, through the National Bureau of Standards—

(1) promote and protect United States interests in international voluntary standardization activities, in cooperation with other Federal agencies and national non-Federal voluntary standards organizations;

(2) provide funding and other necessary support for United States participation in international voluntary standardization activities; and

(3) develop and maintain a long term public and private comprehensive National Standards Policy in cooperation with the Office of Policy, Analysis and Assessment, other Federal agencies and national, non-Federal agencies and national non-Federal voluntary standards organizations.

(h) The Foundation shall, through the National Technical Information Service—

(1) in coordination with existing private and public systems and in cooperation with the Office of Policy, Analysis and Assessment, develop and implement a coherent National Information and Statistics Policy directed to:

(A) the effective operation of the society and the measurement of the important factors influencing the national life quality, including continuous gathering of data on and assessment of current and future United States and foreign technology, professions delivery systems and design;

(B) the promotion of a full array of information and statistical services regarding research and development from Federal laboratories, as well as foreign advancement in the professions, technology and science;

(C) greater access and utilization of the national and private assessment, information and statistical systems by small and large business, academia, the professions, labor, Federal agencies, the State and local government.

(2) promote technology transfer from the Federal Government to private enterprise and assist the Office

of Intergovernment Technology and Professions Delivery Systems in promoting technology transfer to State and local governments;

(3) develop and maintain an organized reporting of information on the historical, legal, technological, commercial, and professions aspects of design in the United States and foreign countries and make this information available for use by the public and private sector.

(i) The Foundation shall create a National Design Council which shall—

(1) through its programs, encourage excellence in technological design, educate United States entrepreneurs and government agencies to the value of excellence in design; encourage such entrepreneurs to promote excellence in design in the creation, manufacture and sale of well-designed objects and systems; and assist other government agencies as their programs relate to the objectives of the Foundation, in developing and encouraging excellence in design in addition to performing their other duties;

(2) establish and publicize standards for excellence in the design of objects and systems, including but not limited to consideration of energy consumption reduction, health and the environment.

(3) consult and cooperate with foreign governments and intergovernmental organizations in collaboration with the Department of State, and with private international organizations which are or become concerned with the encouragement and coordination of increased use of excellence in design, to gain international recognition for design standards proposed by the United States.

NATIONAL PROFESSIONS AND TECHNOLOGY BOARD

SEC. 7. (a) The Foundation shall be operated under the general supervision and policy control of a National Professions and Technology Board which shall consist of (1) twenty-four members to be appointed by the President, by and with the consent of the Senate, in accordance with section 12(b)(1), and (2) the Director, appointed in accordance with section 8(a).

(b) The persons nominated for appointment as members of the Board—

(1) shall be eminent in the professions and technology, including the fields of labor, entrepreneurship, management, education, industry, government, invention, patents and trade and shall be expected to independently represent all segments of the society to avoid dominance by the Federal Government.

(2) shall be selected so as to provide representation from minorities; representation of all geographic areas of the Nation; and equitable representation of all professions, with particular attention given to nominees possessing experience and expertise in more than one profession.

(3) shall be nominated after due consideration of recommendations for nomination made by the Board itself, the National academies, professional societies, business associations, associations of State and local governments, labor associations, or other appropriate organizations.

(c) The term of office of each member of the Board other than the Director shall be six years, except that—

(1) any member appointed to fill a vacancy occurring prior to the expiration of the term, for which the predecessor was appointed shall be appointed for the remainder of such term;

(2) any person other than the current Chairman of the Board, who has been a member of the Board for two consecutive six-year terms shall thereafter be ineligible for appointment during the two-year period following the expiration of the second term; and

(3) of the persons initially appointed, eight shall be appointed for terms ending May 10, 1984, eight

shall be appointed for terms ending May 10, 1986, and eight shall be appointed for terms ending May 10, 1988.

(d) The Board shall have a Chairman and a Vice Chairman who shall be elected by the Board from its members for a term of four years. No person shall serve more than ten years as Chairman of the Board. The Director shall not be the Chairman or the Vice Chairman but shall be eligible to vote on all matters. The Chairman shall chair meetings of the Board and perform functions as specified in this Act. The Vice Chairman shall perform the duties of the Chairman in the Chairman's absence.

(e) The Board shall meet (1) not less than twice annually, (2) at the call of the Chairman, and (3) upon the written request of one-third of the members. A majority of the members of the Board shall constitute a quorum. Each member shall be given ten-days advance written notice of each meeting.

(f) There shall be an executive committee of the Board which shall be composed of five members, including the Director, the Chairman of the Board, the Vice Chairman, and two other members of the Board elected to two-year terms by the Board. The executive committee shall exercise such powers and functions as may be delegated to it by the Board.

(g) The Board shall, in addition to any powers and functions otherwise granted to it by this Act—

(1) establish the policies of the Foundation, in accordance with applicable policies established by the President and the Congress;

(2) review the budget of the Foundation;

(3) review the programs of the Foundation;

(4) render the report of section 14(B) to the President, for submission to the Congress;

(5) approve or disapprove every grant, contract or other funding arrangement the Foundation proposes to make, except that a grant, contract or other funding arrangement involving a commitment of less than $250,000 may be made by the Director without specific Board action, if the Board has previously reviewed and approved the program of which that commitment is part.

(h)(1) The Board is authorized to appoint a staff of not more than five professional staff members and such clerical staff as may be necessary. The professional staff members may be appointed without regard to the provisions of title 5, United States Code, governing appointments in competitive service, and the provisions of chapter 51 of such title relating to classification, and may be compensated at a rate not to exceed the rate provided for grade GS-18 of the General Schedule under section 5332 of such title.

(2) The Board is authorized to establish such special commissions as it may deem necessary for the purposes of this Act.

(i) Members of the Board shall receive compensation when engaged in the business of the Foundation at a rate fixed by the Chairman but not exceeding the daily equivalent of the rate provided for level GS-18 of the General Schedule under section 5332 of title 5, United States Code, and shall be allowed travel expenses as authorized by section 5703 of title 5, United States Code.

DIRECTOR OF THE NATIONAL PROFESSIONS AND TECHNOLOGY FOUNDATION

SEC. 8. (a) The Director of the Foundation shall be appointed by the President, by and with the advice and consent of the Senate. Before any person is appointed as Director, the President shall afford the Board an opportunity to make recommendations with respect to such appointment. The Director shall receive basic pay at the rate provided for level II of the Executive Schedule under section 5313 of title 5, United States Code, and shall serve for a term of six years.

(b) Except as otherwise specifically provided in this Act the Director shall exercise all of the authority granted to the Foundation by this Act.

(c) The Director may make such provisions as he deems appropriate, authorizing the performance by any other officer, agency, or employee of the Foundation of any of his functions under this Act.

(d) The Director shall formulate the programs and budgets of the Foundation.

DEPUTY DIRECTOR AND ASSISTANT DIRECTORS

SEC. 9. (a) There shall be a Deputy Director of the Foundation who shall be appointed by the President, by and with the advice and consent of the Senate. Before any person is appointed as Deputy Director, the President shall afford the Board and the Director an opportunity to make recommendations with respect to such appointment. The Deputy Director shall receive basic pay at the rate provided for level III of the Executive Schedule under section 5314 of title 5, United States Code, and shall perform such duties and exercise such powers as the Director may prescribe. The Deputy Director shall act for, and exercise the powers of, the Director during the absence or disability of the Director or in the event of a vacancy in the Office of Director.

(b) There shall be eight Assistant Directors of the Foundation who shall be appointed by the President, by and with the advice and consent of the Senate. Before any person is appointed as an Assistant Director, the President shall afford the Board and the Director an opportunity to make recommendations with respect to such appointment. Each Assistant Director shall receive basic pay at the rate provided for level IV of the Executive Schedule under section 5315 of title 5, United States Code, shall perform such duties and exercise such powers as the Director may prescribe, and shall have responsibility for one of the following:

(1) the Office of Policy, Analysis and Assessment;

(2) the Office of National Programs;

(3) the Office of the Professions;

(4) the Office of Human Resources;

(5) the Office of Small Business;

(6) the Office of Intergovernmental Technology and Professions Delivery Systems;

(7) the National Bureau of Standards; or

(8) the National Technical Information Service and the Patent and Trademark Office.

(c) The Assistant Director for the National Bureau of Standards shall be the Director of the National Bureau of Standards.

COUNCILS

SEC. 10. (a) Councils shall be appointed by the Director, with advice from the Assistant Directors, to serve as independent public advisory bodies to the Director and the individual offices of the Foundation.

(b) Council members are to represent a wide cross section of United States society including experts in the matters considered by the Office to be advised, general consumers, labor, industry, academia, the public and private sectors, the professions, and science.

(c) The Councils, in response to requests from the Director, Assistant Director or on questions raised on their own initiative, shall investigate and deliberate on the directions of the long term and basic policies addressed by the Foundation and its officers, compatible with the interests of the public. The Councils shall serve as deliberative public forums for current and future important national policies.

(d) The Council for Policy, Analysis and Assessment shall produce an annual review of national needs, problems, and opportunities with an analysis of the progress made to satisfy these needs including an assessment of the performance of existing public and private institutions.

(e) Each council shall include such committees as shall be found necessary to satisfy the purview of the council.

GENERAL AUTHORITY OF THE FOUNDATION

SEC. 11. (a) The Foundation shall have the authority within the limits of available appropriations, to do all things necessary to carry out the provisions of this Act, including but not limited to, the authority—

(1) to establish additional offices and other organizational structures within the Foundation;

(2) to prescribe such rules and regulations as it deems necessary governing the manner of its operations and its organization and personnel;

(3) to make such expenditures as may be necessary for administering the provisions of this Act;

(4) to enter into grants, contracts, cooperative agreements, or other arrangements with whatever persons, organizations, countries, or other entities are deemed most useful by the Foundation to accomplish the purposes of this Act;

(5) to acquire, hold, or sell real and personal property of all kinds necessary to carry out the purposes of this Act;

(6) to receive and use funds and property donated by others, if such funds and property may be used in furtherance of the purposes of this Act;

(7) to accept and utilize the services of voluntary and uncompensated personnel and to provide transportation and subsistence as authorized by section 5703 of title 5, United States Code, for persons serving without compensation;

(8) to arrange with and reimburse other Federal agencies for any activity which the Foundation is authorized to conduct;

(9) to receive funds from other Federal agencies for any activity which the Foundation or the other agencies are authorized to conduct; and

(10) to appoint and fix the compensation of personnel necessary to carry out the provisions of this Act.

(b) Except as provided otherwise in this Act, appointments under subsection (a)(10) shall be made and such compensation shall be fixed in accordance with the provisions of chapter 51 and subchapter III of chapter 53 of title 5, United States Code, except that the Director may, in accordance with such policies as the Board shall prescribe, employ technical and professional personnel and fix their compensation, without regard to such provisions, as is deemed necessary to carry out the purposes of this Act.

NATIONAL PROFESSIONS AND TECHNOLOGY MEDAL

SEC. 12. (a) There is hereby established a National Professions and Technology Medal, which shall be of such design and materials and bear such inscriptions as the President, on the basis of recommendations submitted by the Foundation, may prescribe.

(b) The President shall periodically award the medal, on the basis of recommendations received from the Foundation or on the basic of other such information and evidence as is deemed appropriate, to individuals who in the President's judgment are deserving of special recognition by reason of their outstanding contributions to the promotion of the professions, technology and technological manpower for the improvement of the economic, environmental or social well-being of the United States.

(c) Not fewer than three nor more than twelve individuals shall be awarded the medal in any one calendar year.

(d) The presentation of the award shall be made by the President with such ceremonies as may be deemed proper.

COORDINATION OF PROGRAMS

SEC. 13. (a) The Director shall insure that all programs of the Foundation are coordinated with other programs of the Federal Government, with the private sector, and with the State and local government programs.

(b)(1) A standing National Foundation Coordinating Board comprised of five members from each National Foundation (NPTF, NSF, NFAH) Board shall be appointed and shall meet at least twice a year to provide recommendations to improve the collective effectiveness of the three foundations in the national interest.

(2) To the greatest extent feasible, extramural basic research fields which the National Professions and Technology Foundation wishes to support shall be supported through the National Science Foundation programs by transfer of funds to the Science Foundation.

(3) The Foundation shall coordinate studies in societal value systems and ethics with the applied humanities programs of the National Foundation on the Arts and Humanities.

(c) The Foundation shall coordinate its small business activities fully with those of the Small Business Administration and shall not conduct any small business program which the Administrator of the Small Business Administration finds to be duplicative of that Administration's programs.

(d) The Foundation is authorized and directed to provide assistance to the Office of Science and Technology Policy upon request.

SCHOLARSHIPS AND GRADUATE FELLOWSHIPS

SEC. 14. (a) The Foundation may award scholarships and graduate scholarships for the study of the public professions.

(b) Any scholarship or graduate fellowship awarded under subsection (a) shall—

(1) be for use at any educational institution selected by the individual receiving such scholarships or graduate fellowship;

(2) be made only to citizens of the United States; and

(3) be made on the basis of ability.

REPORTS

SEC. 15. (a) The Foundation shall transmit a report to the President for submission to Congress not later than one year after the Board has been duly organized and each odd numbered year thereafter. Each such report shall contain a detailed statement of the activities of the Foundation and the important national policy issues and emerging problems and opportunities, along with the Foundation's recommendations for such legislation or other action deemed appropriate.

(b) In addition to reports required by subsection (a), the Foundation shall make any study or report ordered by either House of the Congress, by any committee of either House, or by any joint committee of the Congress.

(c) At the request of either House of the Congress, of any committee of either House, or of any joint committee of the Congress, the director of the Foundation shall furnish such House or committee with such assistance or information as it may request.

MISCELLANEOUS PROVISIONS

SEC. 16. (a) The Director may exercise any authority available by law to the Secretary of Commerce with respect to any entity transferred by section 5(c) and the actions of the Director in exercising such authority shall have the same force and effect as when exercised by such Secretary.

(b) At any time more than one year after the date of enactment of this Act, the Director, with the approval of the Board, may allocate or reallocate functions among the organizational components of the Foundation and may establish, consolidate, alter, or discontinue such components as may be necessary or appropriate.

(c) The Director may establish, alter, discontinue or maintain such regional or other field offices as the Director may find necessary or appropriate to perform the functions of the Foundation.

(d) The Director may, when authorized in an appropriation Act in any fiscal year, transfer funds from one appropriation to another within the Foundation, except that no appropriation for any fiscal year shall be either increased or decreased pursuant to this subsection by more than 5 per centum and no such transfer shall result in increasing any such appropriation above the amount authorized to be appropriated therefor.

(e) Chapter 53 of title 5, United States Code, is amended—

(1) by adding at the end of section 5313 the following new paragraph:

"Director, National Professions and Technology Foundation";

and

(2) by adding at the end of section 5314 the following new paragraph:

"Deputy Director, National Professions and Technology Foundation".

(f) Section 10 of the Stevenson-Wydler Technology Innovation Act of 1980 is repealed.

AUTHORIZATION OF APPROPRIATIONS

SEC. 17. (a) There is hereby authorized to be appropriated to the National Professions and Technology Foundation for the fiscal year 1984, for the following categories:

(1) Office of National Policy, Analysis and Assessment, $20,000,000;

(2) Office of National Programs, $200,000,000;

(3) Office of the Professions, $250,000,000;

(4) Office of Human Resources, $100,000,000;

(5) Office of Small Business, $40,000,000;

(6) Office of Intergovernmental Technology and Professions Delivery System, $40,000,000;

(7) National Bureau of Standards, $150,000,000;

(8) National Technical Information Service and the Patent and Trademark Office of the Department of Commerce, $80,000,000;

(9) National Design Council, $10,000,000; and

(10) other purposes of this Act, $9,000,000.

APPLIED SCIENCE IS PURE NONSENSE IN MYOPIC BRITAIN

(The Times Higher Education Supplement 19.3.76)

I have previously argued in The Times(August 29, 1975) that Britain has a tendency to bias debate about cultural issues away from considering the production of useful artifacts and towards the fine arts, knowledge and science.

Lord Clark's book Civilisation illustrates this trend. Although he admits that the useful arts are essential for his idea of the civilized life his treatment implicitly denies this view. The potter and ironmaster are forgotten, even though they are essential supporters of the painter and architect.

Responses and classifications of this type are peculiar to a culture dominated by the English language, and have helped to generate a state of mind in which the useful is devalued in importance. The dreaming towers of the Academy reinforce the view, adopting the bizarre potion of "applied science" which, by the very phrase, implies the seamier side of "pure science".

In other European countries, the classification and implied relative importance of parts of the cultural and sub-cultural jungle look quite different. In Germany, for instance, if the man on the Düsseldorf tram is heard talking of differences between the "two cultures", the assumed split is invariably between Technik--making useful objects--and the rest.

More commonly however there is a three-way separation into Kunst, Wissenschaft and Technik--art, a broader conception of science than our normal one, and manufacture--which form the subject of this article. There are three main points to be made. First, the continental conception banishes a British nonsense, whereby history and sociology, both studies of man in society, can have crept into separate cultural camps.

To the University Grants Committee and to those who think as its system of classification provokes, history (or at least the teaching of it) is part of the "arts"; sociology is part of "social studies". In Germany, in contrast, both are unashamedly part of Wissenschaft, the scientific approach to knowledge. Geography, an "art" subject to the UGC, sensibly becomes a German-style "science".

Second, the K-W-T cultural system reflects a long-existing pattern of separation in higher education in Germany, and in those many countries which have followed Germany. Wissenschaft includes all the topics taught in the classical universities.

Technik in contrast, has generally been taught in Europe in separate technical universities, quite outside the classical universities. Kunst, the fine arts, has been taught in a number of separate schools and conservatories. So each has its cultural shrine; and no one with a university background is a German-style "arts" graduate.

A third point is that,as already implied, Wissenschaft, including all formally expressed knowledge, is quite different from out first meaning of "science", which makes "pure science" much the same as natural science. Indeed in another sense, Wissenschaft denotes a method, the empirical approach to knowledge of all sorts, and is not uniquely connected with natural events.

Any system of classification tends to have its anomalies, especially one which attempts to group together very diverse elements. One in the K-W-T. system is that a piece of creative writing in fiction is included within Kunst: whereas literary criticism is classed as "science" and part of Wissenschaft. So the novels of Jane Austen are found on quite different shelves from their appreciations.

The most obvious difference between the continental and the English-language systems is that the very existence of Technik separates natural science from the useful arts. It also dignifies manufacturing as an aim which is important without reference to the norms of "science" or "art".

The English habit of calling engineers "scientists" is therefore both astounding and meaningless to the typical European. So is the English-language idea of a "science-policy," which tends to include elements of so-called "applied science". Those with Nobel prizes in physics or biology are less likely to be heeded on topics of manufacturing in Germany than in Britain.

To an anthropologist the idea of culture is closely bound up with the skills in the useful arts. Did this particular people know how to fashion metals? Could they cultivate the land? What sort of tools had they developed? Groups and civilizations become known by the useful artifacts which they left behind: Stone Age, Bronze Age, the pottery Neolithic Age.

Given such acknowledgement of a social and cultural preoccupation with the useful, should present societies be classed in a different way? Or has something happened so significantly in cultural development that other main indicators should be used? For it can be argued that increased living standards in the present developed world make it more sensible to think of these cultures differently from more primitive ones, and the ensuing argument can therefore be framed in two alternative ways.

First, assuming that the approach of anthropologists is still applicable, and that there has been no substantial break in cultural development, the English language treatment of cultural and subcultural areas is not only myopic; is it reckless.

It is myopic because it assumes, through its dogged insistence on an "applied science" reading of the process of continental Technik, that technical change is intimately concerned with changes in the use of knowledge of natural science. Evidence from case studies indicates that this is not the case.

The "applied science" conception is reckless because it assumes quite wrongly, that those who have the boffins also have the power. In truth, possession of scientific knowledge simply does not transmit easily into economic and industrial strength.

The alternative position assumes that there has been a major break in cultural development somewhere, say, between the eighteenth century and today.

What, therefore, makes our English-language cultural analysis so inept, and the European K-W-T system more suitable than ours? The answer again lies with Technik and the ridiculous English-language idea of "applied science" hallowed in UGC usage.

The "applied science" idea is misleading for at least four reasons. It implies, erroneously, that there can be a matched idea known as "pure science". It implies, equally erroneously, that the manufacture of useful products can be characterized as the use of natural science in a practical setting. It degrades a number of important functions in industry. And it misinforms outsiders about these functions.

The idea of purity denotes some sort of measure of applicability or utility in practice. However, there can never be any body of "pure science" in these terms, since all knowledge is potentially applicable and useful, and no one can ever be sure when a particular piece of knowledge is used.

Even the phrase "applied science" is a misleading concept. If it means part of Technik, the manufacture of useful artifacts, it is wrongly named. The one feature common to all scientific work is that its main output takes the form of knowledge; whereas work within Technik has as its goal a product or process.

If "applied science" is meant to describe scientific work undertaken in order to be applied in manufacturing or in other practical situations, it is wrongly named for the reason argued above. There is no contrasting body of "pure science." So all scientific knowledge is "applicable science" and there is no meaningful contrast between "pure" and "applied".

The other three points can be dealt with briefly. First, almost all empirical investigations of industrial innovation (major changes in product or process) indicate that innovation is not typically the result of new use of knowledge derived by natural science.

New artifacts tend to derive directly from older artifacts. The vigour and determination of individuals is usually a more important factor influencing success, than any connection with science. Besides this, general technical change, continuous rather than consisting of discrete steps, is even less influenced by changes within natural science.

The adoption of the "applied science" construct, impossible in the European K-W-T system, is based on a connexion between natural science and manufacturing which does not exist. It therefore distorts the general and lay understanding of the manufacture of useful artifacts. In particular it helps to devalue the assumed importance of production and product design in the manufacturing context.

Thus, even if the Victorians were right about cultural development, we are wrong to neglect the Technik idea and adopt "applied science" instead, purely on the grounds that the latter idea is a nonsense.

In my earlier paper, I mentioned the English recumbent hero. To the intellectual this is a Keynes lying in this bath successfully phoning his stockbroker; to other English people and to most foreigners, an aristocrat with his effortless ease.

A hero of this type is typically someone of great achievement and distinction who has not had to work hard for it. The workshop of effortless ease is a Victorian hangover and longlasting English mirage for prosperity and success. No desert Bedouin ever saw a goal so beguiling, so diverting, and so capable of his total disorientation.

Oxbridge high tables seem to be the shrine for British cultural discussion. Those who live there in the cultural box called "science," by adopting the foolish and inaccurate "applied science" construct, have allowed the average Briton to imagine that he can obtain a form of material salvation by science, rather than by intelligent effort.

In the continental European way of thinking, this is impossible. Neither moonshot nor transistorized communication, nor industrial progress is much concerned with "science." Each is to do with Technik, which the Academy in Britain does not really want to know about.

Those in the high table "arts" box have accepted some of the scientists' assumption. To them "art" is superior to "science," since it provides more scope for individual flair and creativity. Nodding to the scientists, the arts man notes that there are two parts to the other side of the gulf. And "pure" provides more of a challenge that "applied": everyone in the Cavendish agrees about that.

It is well known, so the argument goes on that those within the "science" box who are not up to plumbing the great secrets of nature are consigned to detailed problems of nuts and bolts of far lesser importance. Do not shout too loud about it, the "arts" people do on; but Lord Clark is right. Art's product is what man is sensibly most proud of, as it forms the major part of his heritage.

This archetypical English "arts" line of reasoning, neat but misleading, is at the best, and on the second assumption of this paper, a foolish incantation by those who congratulate themselves for having avoided involvement with the drudgery of physics or manufacturing.

At the worst, and on my first assumption, it is the foundation of the slow suicide of a group: a sure way of how not to succeed as a nation without really trying to discover why. Any grasp of the Technik conception would help in this discovery.

MICHAEL FORES

Mr. WALGREN. Well, thank you very much, Dr. Rosenstein. That's a powerful statement and it certainly rings a lot of bells in my reaction to what I have seen in Pittsburgh, in any event, particularly in terms of adversary relationships between parts of our economy that have to function together and in the inability of present Government mechanisms to function in an inclusive fashion. I wanted to also say how positively I respond to the idea of someplace where all these questions will—where responsibility to at least ask all these questions, including what happens to the people if you do nothing, are asked and where some responsibility is felt. I often think that we pride ourselves on the change that our society goes through. I think particularly of the agricultural sector where we point with such pride that we now produce more than we used to with only 2 or 3 percent of our population compared to, in historical terms, where 70 and 80 percent of our population were on the farms. But nobody really asks the question: What happened to those people in that process of change? For some it worked out and for some it didn't work out, and for those that it didn't work out—largely in the center cities of America—we have created by not asking that question that I see your suggestion as a foundation at least leading us to ask, we have created dramatic social problems that threaten literally the lives of the people we care about the most, which is our children. So I really want to underscore that aspect of your testimony and I find it strong.

I would like to recognize the other members on the panel for any thoughts and concerns. Mr. MacKay?

Mr. MACKAY. Dr. Rosenstein, what you are suggesting basically is that we broaden our time frame and look a little further ahead while we are looking at basic questions like whether the Government should confine its interest to basic science. You are saying that structurally we don't have a mechanism to enable us to adapt to the world that's coming at us.

Dr. ROSENSTEIN. It may frighten us and we may not want to look ahead, but I think if there is any element in our society that has both the resources and the responsibility for anticipating not only problems but opportunities, that responsibility lies within the Federal Government.

We spend hundreds of millions of dollars gathering information, as the Grace Report shows, in a totally ineffective fashion. If we would just take the same resources and organize them toward an international and domestic data base concerned with all facets of our society, including our industrial competence, and then make this readily available—which is easily within the capability of our technology—we could save hundreds of millions of dollars and the Government could provide a service to our society which would be of incalculable value.

Mr. MACKAY. You have in your written testimony a paper entitled "Policy Versus Planning," and you are basically suggesting that we develop a mechanism which would enable us to go through a process of consensus-based policy setting. Is that correct?

Dr. ROSENSTEIN. Exactly.

Mr. MACKAY. That would be different from Government-imposed planning.

Dr. **Rosenstein**. You put your finger on the basic problem and the only way out that I see. I teach something called systems engineering, and I don't want to attempt to define it, but in anything as complicated as our society, if you start thinking about centralized planning and the time it takes to gather your information, assess your alternatives, devise your plans in infinite detail and then educate and disperse those plans, you quickly find out the dynamics of our society overrun any practical time scale you might have. Centralized planning, whether you like it or not, is simply impractical. In a society that's changing as fast as ours is, the plans will be obsolete before they can be implemented.

But, on the other hand, if there are no policies that the society can look to, then no one knows what to do and they instinctively fall back. Let me give you an example of what I mean: Many of my friends who are very conservative people have been hurt by the policies of the Government which restricted inflation. Now all of us are against inflation, but I observe this sort of thing happening: Inflation went on for so long that conservative people on salaries, with fixed incomes, began to realize that their savings were being eroded. Their real income was becoming less and less, and they frantically began to look for something to do. They were up against it.

Many of them realized that what was continuing to stay up with the inflation was real estate—houses, apartments—so they bought inflated real estate at high interest rates with the expectation that the inflation would let them pay it off. Now the moment the inflation was cut back, these people were hurt and hurt very badly. Many of them have lost their investments entirely.

You might say, were they foolish? No, they weren't foolish. Were they speculators? No. They were trying to build a hedge to maintain their life savings, to retain what they had, and this shift in policy—even though we all admit it was a desirable shift—left them stranded. What I am saying is, you can even have bad policy so long as it's consistent. The society itself will do the planning if it only knows what the game policy is.

Mr. **Boehlert**. Doctor, if I may just interject a minute, if my colleague will yield, you have just eloquently outlined the problem of the American farmer.

Dr. **Rosenstein**. I imagine, yes. Yes, as the policy changes, what does he plant?

Mr. **MacKay**. Well, let me just carry that forward a little further, if I might. Let's take the problem of the American farmer or the problem of the American clothing worker, and let's assume that what you outlined briefly in the manufacturing of clothing is a proxy for a lot of other industries. Let's say you said let's work on the basic problem from now to the year 2000. The real basic problem is that we better develop some meaning in life besides vocation.

Dr. **Rosenstein**. Well, if only 8.3 percent of the working population is engaged in manufacturing, and we presume the others are going to have an income—I have unlimited faith in the ability of the human animal to think of new ways to serve himself. In other words, I don't think it's bad or unusual that the services are expanding, if we can only have a manufacturing base upon which to build.

I alluded to the ultimate problem of this century. The ultimate problem in this country is how do we maintain a manufacturing base adequate to provide enough value added to offset our import requirements. If we don't provide enough value added in our manufacturing base, then it is inevitable that to balance the equation, the standard of living of the country must go down. There is no way to keep importing more than you export in values. There is ultimately going to be a leveling of the count, and that usually comes by reducing wages and reducing income.

We need some mechanism to look ahead, to look at those areas in which we have or can create a comparative advantage and in which we can retain a manufacturing base, it doesn't make any difference what that area is, whether it is smokestack or high technology, but there is going to have to be some comparative advantage which will allow us to retain it. The mobility of technology and money is so great these days that I can have a factory set up in Malaysia building the most complicated electronic gear within 1 year, and that never existed before. It's a very difficult problem and I think the longer we spend not addressing this problem, the longer it is going to take us to climb out of the hole in which we're descending.

Mr. MacKay. But one of our major problems, "our" being the people sitting on this side of the table, who represent the people of America in every sense of the word—we represent their fantasies, their ignorance, we represent everything—and one of our major problems is, we don't yet have a common perception of that reality which you have outlined, and therefore we are caught up in these irrelevant political arguments about industrial policy and Government planning. We heard the Assistant Secretary of Commerce yesterday just simply say, "We are against it—it is our position that all of this is wrong because it represents Government planning." Therefore, you know, it's like I've got a set of blinders on and unless you can move the future to directly in front of me, and if I happen to be looking backward, then they are basically saying "We are not going to discuss anything that's outside of this set of blinders we've got on." What you're saying is, "Well, wait a minute. That set of blinders no longer encompasses the reality of the world."

Dr. Rosenstein. I think it's true. The data seems to be incontrovertible. I mean, you just take case after case to show industry after industry that is either gone or will go as the garment industry will go, unless we recognize it and put a mechanism in place which enables us to make cooperative decisions.

I am not advocating that the Government plan. I said earlier that centralized Government planning, particularly for an economy, must fail. I also say that the lack of consistent national policy will ensure failure because no one will know how to run his plant, where to make his investments, unless he knows where national policy is going.

At the same time, the cost of playing the manufacturing game is going up. The cost of new development has gone beyond the capability of most individual companies. Japan put $2 billion into the development of their very large scale integrated circuits. How many companies in this country beside IBM can invest $2 billion in a single development? No way. The same problem on a smaller scale is what we're facing in the garment industry. I don't think any single garment manufacturer is large enough to finance the D&R—development and research—necessary to develop an unmanned garment factory, and yet our competitors are doing it and it's a reality that our garment industry must face and we as a nation must face or suffer the consequences.

Mr. MacKay. Basically, the next logical step then is, can each sovereign nation continue to develop policies which assume that it can only succeed at the expense of others?

Dr. Rosenstein. You probably ought to go off the record because it sounded like you were advocating world government——

Mr. MacKay. No, I'm not. Just like you're not advocating planning, I'm not advocating world government. [Laughter.]

Dr. Rosenstein. Well, I believe—thank you.

Mr. MacKay. What I am saying, maybe we ought to get all the facts there and then suddenly people might come to a consensus different from our political rhetoric.

Dr. Rosenstein. I think that's it, because the facts of life indicate the world plays a zero sum game. What one nation gains, another nation will lose, unless we start concentrating in each nation upon those things that we do well.

I used to do consulting down in Venezuela, and American universities had gone down there and told them that they ought to do atomic research. I wasn't in a crying mood but if I were, I could have cried over it. Here was a nation that had some of the largest natural energy resources in the world, and we were advising them to take their brightest people and put them in atomic power research instead of devoting their energies to the exploitation of some of the heavy tar sands that they've got down there.

The time must come where we provide the means of gathering enough information so each nation can see what it can do best, so that we can have a more efficient world economy. I don't know that we'll live to see it but I think that's the goal for which we're ultimately going to have to strive.

Mr. MacKay. Thank you. This has been fascinating.

Mr. Walgren. Thank you, Mr. MacKay.

Mr. Boehlert?

Mr. Boehlert. Thank you, Mr. Chairman. We're getting very philosophical here this morning.

I think you were so correct when you pointed out and quoted the Murrin article. Is that the right name?

Dr. Rosenstein. Yes, sir.

Mr. Boehlert. When he said in his article that meeting the Japanese challenge is beyond the reach of any one company here in the United States, of course that's true. When we talk about the Japanese challenge we're not talking about Toshiba or Sanyo. We're talking about the total challenge from their government and industry working cooperatively, and I would agree with you that there is a desperate proven need for more of a leadership role in our Government. I would agree with some of the administration officials who have appeared before our committee.

You have given us more than food for thought. You have given us a whole banquet. Let me give you a challenge if I may.

Mr. **Rosenstein**. Please.

Mr. **Boehlert**. I'm going to do my best to digest and learn from your comprehensive statement.

One of the things that I'm really concerned about—and this is going a little bit far afield—but I think your projections are accurate. Ten years down the road I can see those 2 million garment workers unemployed, and I think we have to respond now to that inevitability. For that reason, I am going to take the liberty of sending you a package on a bill that I am a principal author of which would establish individual training accounts for workers. Are you familiar with that concept at all?

Mr. **Rosenstein**. No, I'm not.

Mr. **Boehlert**. Just let me give you a very brief capsule of the concept. We know that in the 1990's we're going to face, because of changing technology, the prospect of millions of American workers like those in the garment industry who are going to be displaced. We ought to start planning now to take care of their needs then. Under the individual training account concept—and it is gaining some support, we have bipartisan support in the House—the workers and the employers on a voluntary basis would enter an arrangement under which the employee would contribute eight-tenths of 1 percent or up to a maximum of $250 in 1 year to an individual training account. That would be matched by the employer, would accumulate and gather interest. It would be invested by the U.S. Treasury Department in high yield securities until there was a $4,000 account which would continue to gain interest benefits, and then the employees and employers would stop contributing.

Ideally the employee would never have to use that account. When he or she retired, they would be able to withdraw the contributions plus interest and use it for retirement purposes, but when the inevitable occurs—and it will in the lives of so many American workers who genuinely want to work but they are going to find one day that they have got a pink slip, they are displaced by technology—the employee can take and draw from that individual training account to finance training in a skill area where there is a proven need for the skill. It's a concept that I am very excited about and I'm doing my best to get a lot of other people excited about it, and I would appreciate your taking a look at the package you are going to get in the mail shortly and I would welcome your comments, because we just have to deal with the change in the world as we see it right now in an effective manner, to really be concerned about people.

Dr. **Rosenstein**. You have identified a critical problem that's going to become even more critical. I was with someone the other day and they said that when they looked at the people who are receiving relief, contrary to the mythology there is a turnover. This would indicate that there are people who do lose jobs through no fault of their own, who go on relief and who do require retraining to come back into the society and the industry as fast as possible, and we certainly need a mechanism such as you have described.

Mr. **Boehlert.** Well, you will be hearing from me, and I want to thank you very much for your comprehensive and thoughtful statement.

Dr. **Rosenstein.** Thank you.

Mr. **Walgren.** Thank you very much, Mr. Boehlert.

On behalf of the committee, we want to express our appreciation. These are good guides for us and stimulating guides, so we appreciate your being a resource to the committee.

Dr. **Rosenstein.** Thank you very much.

Mr. **Walgren.** The last witness today is Dr. John Alic, who is a project director with the Office of Technology Assessment.

Welcome to the committee, Dr. Alic. I know we have gone on for longer than we usually do with the witnesses this morning but they have warranted it, and the subject matters that they have been concerned with certainly deserve the attention and the time of the committee, but know that your written statement will be made part of the record and in view of the time, if you would zero in on points that you really want to underscore, we would appreciate it.

STATEMENT OF DR. JOHN A. ALIC, PROJECT DIRECTOR, OFFICE OF TECHNOLOGY ASSESSMENT

Dr. **Alic.** I will do that, Mr. Chairman. Thank you.

Mr. Chairman and members of the subcommittee, thank you for inviting OTA to testify on manufacturing this morning. I will summarize very briefly, focusing my comments on the two bills, H.R. 4047 dealing with Robotics and H.R. 4415, the Manufacturing Sciences and Technology Research and Development Act.

Our analysis indicates that both these bills could help to set higher priorities for manufacturing technologies in the United States and, through that, help the international competitiveness of many American industries. We at OTA have spent more than 5 years studying the international competitiveness of manufacturing industries in the United States., and in many of the specific industries and subsectors of industries that we have looked at we have found problems that can be traced to manufacturing technologies.

And, as many of the witnesses this morning have pointed out, we are entering an era in which there will be radical changes in the technologies of manufacturing, centered around the use of the computer, the use of robotics, but I think even more broadly what we'll be seeing through the rest of the century is a reintegration of product design and manufacturing, functions that really since the dawn of the mass production era in the early part of this century have been isolated, at least in our larger corporations. The computer is helping to bring these functions back together. That is one of the sources of displacement in the workforce in our manufacturing industries that we will have to learn to adjust to and deal with in the years ahead.

In other words, it is not only the production workers that will be replaced by robotics or other forms of automated manufacturing equipment; it's lower-line supervisory personnel; it's clerks on the factory floor who used to keep track of production, used to keep track of the supplies in the tool crib; expediters; all the people that made factories function are finding now that they are doing their jobs with machines and that machines—that is, computers in many cases—are taking over more and more of the functions that the people used to do. So I would emphasize that it is not only production workers, and it is not only the robot that is changing the face of our manufacturing industries. It is a much broader change than that that is ahead of us, and the source of this is the reintegration of the production system as a system.

Now I have focused in the last few comments on the people side of that problem. The other side of that and the driving force, of course, is that it improves the efficiency of industry and carries great potential for American industry to improve its international competitiveness and, as we have heard this morning, that is very important in manufacturing as a road to meeting competition from Europe, from Japan, and also of course from the newly industrializing countries.

But I certainly agree with the emphasis that Dr. Tesar placed earlier on the man-machine interface and human capital, because it is here that the machine or the computer and the people in the factory system and in our corporations, in our labor markets, come together. While the two bills emphasize, justifiably, the systems integration aspect of manufacturing technologies, I would urge that the subcommittee think carefully about ways of strengthening the emphasis on systems integration and in particular the emphasis on how people can interact more effectively with the equipment that we are putting into our factories, and in particular how the allocation of responsibility between people and machines can be handled. That allocation of responsibility is one of the keys to the efficient functioning of a production system, a factory, a corporation, and that is—if there is a secret—that is the secret to the Japanese factories that have gotten so much publicity in this country. It is not the pieces of technology in the factories, it is not the people or the way the people are managed; it is the whole system, the way it is integrated, the way it functions.

It's difficult to encapsulate that in simple form but I have tried in my written testimony to explicate how that works, and I have used an example from the microelectronics industry, dealing again with a very well publicized episode, the quality differences in large-scale integrated circuits produced in the United States and Japan a few years ago, to try to illustrate how the systems aspects of manufacturing and in particular the integration of the design of the product, the design and layout of the factory that makes the product, and the integration of the people who are an intrinsic part of the functioning of that production organization, all those together affect most critically the output, whether it is quality, whether it is productivity.

If I may turn then more specifically to the two bills, H.R. 4047 and H.R. 4415. Of course H.R. 4047 is the narrower of the two, focusing on robotics and computer integrated manufacturing. H.R. 4415 is considerably broader. In general, the mechanisms for implementation spelled out in H.R. 4047, the robotics bill, appear preferable. Let me take just a moment to explain why I say that.

Under H.R. 4415, the Secretary of Commerce through the Office of the Assistant Secretary for Productivity, Technology, and Innovation, would be given responsibility for grant funding of research projects plus the option of establishing cooperative R&D programs. The Department of Commerce, leaving aside the National Bureau of Standards, has little expertise in technology—that's not a criticism, it simply hasn't been their job—and little experience in operating competitive R&D programs.

H.R. 4047, in contrast, not only provides for an external program review board but would give most of the funding authority to the National Science Foundation. While OTA has reservations concerning NSF's past support for technology development—and I have touched on those in some detail in my written statement—most of these reservations concern priorities or funding levels. By raising priorities for manufacturing within NSF, H.R. 4047 would avoid at least some of these problems.

OTA's work, in particular our recent staff memorandum on technology development and diffusion, would indicate that the best prospects for strengthening the longrun competitiveness of U.S. manufacturing industries might come from combining the breadth of H.R. 4415 with the implementation mechanisms in H.R. 4047. I say that * * * I have skipped over many of the portions of my prepared statement which provide the background for that but, in essence, there are many, many types of metalworking, manufacturing technologies that would be supported by H.R. 4415 which our studies of competitiveness indicate to be of great importance for the future of American industry.

The objective, then, could be a network of technology development and diffusion centers focused on manufacturing and following the Stevenson-Wydler model, though eligible for continuing Federal funding—something, again, that our analysis indicates to be important and I have explained the reasons for that. Most simply, this could be accomplished by incorporating the list of manufacturing processes and methods which appears in section 5(a) of H.R. 4415 into H.R. 4047 with minimal other changes to the latter.

In conclusion, let me note that it is too early to tell what coming generations of integrated production systems will bring us, what they will look like, how they will perform, in which industries they will have their earliest and greatest impacts, how they will affect our labor force, our population. It is not too early to say that computerized design and production will profoundly affect the nature of work, the structure of organizations, and the international competitiveness of American industries.

Given a world economy with a huge excess of labor, mostly in lesser developed countries with low wages and living standards, the United States has no real option but to rely on its technological resources to remain competitive, as Chairman Fuqua pointed out earlier this morning. We will have to do this while finding new ways to meet people's desires for satisfying work and the living standards that Americans expect.

Two or three decades from now, looking back, we will see that the changes in our manufacturing sector have in total been sweeping, even though as they come in real time they may seem piecemeal and incremental. The factory of the future will be visible only with hindsight but this is the way technology works and this is the context within which H.R. 4047 and H.R. 4415 should be viewed.

Thank you.

[The prepared statement of Dr. Alic follows:]

STATEMENT OF

JOHN A. ALIC

PROJECT DIRECTOR, OFFICE OF TECHNOLOGY ASSESSMENT

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

JUNE 13, 1984

Mr. Chairman and members of the Subcommittee, thank you for inviting OTA to testify on technological innovation, and particularly on manufacturing. My statement will draw together findings from a number of OTA assessments, conducted in several programs, as well as our recent Staff Memorandum "Development and Diffusion of Commercial Technologies: Should the Federal Government Redefine Its Role?" That Memorandum builds upon more than five years of experience by OTA staff in analyzing the international competitiveness of American industries. OTA's study Computerized Manufacturing Automation: Employment, Education, and the Workplace, published in April of this year, also bears directly on the subjects the Subcommittee has asked OTA to address.

I will begin by commenting on the significance of technology -- both product designs and process technologies -- for competitiveness. Not only is the development of new technologies -- quite a different matter than the development of new scientific understanding -- vital for maintaining and strengthening the competitiveness of U.S. industries, but so is diffusion of technology to American firms which could use it to improve their products or reduce their costs.

OTA's assessments indicate that low priorities for manufacturing technology in both private and public sectors have harmed the competitiveness of many American industries. H.R. 4047, the Robotics and Automated Manufacturing Systems Research and Education Act of 1983, and H.R. 4415, the Manufacturing Sciences and Technology Research and Development Act of 1983, could help set new priorities and, through this, strengthen U.S. competitiveness. My statement will include a number of comments on these bills.

INTERNATIONAL COMPETITIVENESS: WHEN IS TECHNOLOGY IMPORTANT?

OTA has asked this question in a number of assessments, including U.S. Industrial Competitiveness: A Comparison of Steel, Electronics, and Automobiles, published in 1981, and International Competitiveness in Electronics, issued late last year. Collectively, we at OTA have examined industries ranging from steel to pharmaceuticals, automobiles to computers. Briefly, technology is most important when it permits companies to design and make products that their competitors cannot match or when it permits them to manufacture relatively straightforward products more cheaply. In years past, American semiconductor firms with advantages in product technologies were able to supply integrated circuits beyond the capabilities of companies elsewhere in the world. New technologies for producing galvanized steel sheet, a very different example, have not only cut down on corrosion of automobile bodies but have helped American steelmakers retain a major share of one of their more lucrative markets.

In other cases, technical knowledge is secondary. Most consumer electronic products are designed and built using relatively standardized product and process technologies -- available to companies in many parts of the world. Even so, creative engineering design can lead to successful product offerings. Not only television sets but many personal computers fall in this category.

DEVELOPING AND DIFFUSING COMMERCIAL TECHNOLOGIES

Technology and Science

By and large, technology as viewed above has little to do with science. Certainly scientific research leads to technological advance, which may then translate into competitive advantage. The laser beam has been turned not only to retinal surgery but to localized heat treatment of valve seats for automobile engines. Techniques of operations research, developed as management aids for allocating scarce resources during the Second World War, now help minimize inventories in factories.

Sometimes, as in both these examples, the coupling between scientific advance and technological application is close. Other times it is loose.

Modest knowledge of the physics and chemistry of surfaces has not stopped us from fabricating integrated circuits, utilizing diffusion bonding in aircraft structures, or learning a great deal about the phenomenology and applications of chemical catalysis. Plainly, continued scientific advance will be indispensable to the future competitiveness of American industries. Just as plainly, a strong science base does not translate automatically into competitive success. If the Federal Government wishes to support commercial technologies, it must do more than fund scientific research.

Government Support for Technology

As OTA emphasized in the Staff Memorandum cited above -- excerpts from which are included as an attachment at the end of this statement -- the U.S. Government is not organized to support technology development except through mission-oriented agencies such as the Department of Defense and the Department of Health and Human Services. Indeed, military R&D presently accounts for 70 percent of all Federal R&D spending. While the missions of Federal agencies overlap the domains of product and process technology within which much of American industry operates, these agencies have objectives that may be far different from those of private industry. Recent controversies over export control are only the most obvious example.

OTA's studies point to many reasons why the United States might wish to support R&D with applications to industrial technology within the Federal Government. Perhaps the most compelling is this: American industry now competes in a new international environment, a world where technology is widely available and can move easily and quickly across national boundaries. Other governments have recognized the importance of commercial technologies and designed programs, often as parts of more comprehensive industrial policies, to strengthen the technical resources available to domestic firms. As yet, the United States has not done so. Although the Stevenson-Wydler Act, P.L. 96-480, could provide a framework, few of the provisions of that Act have been implemented. Centers of Industrial Technology in robotics, as provided for in Sec. 5 of H.R. 4047, could be a significant step in moving toward a network of technology centers. OTA's analyses indicate the potential importance of such a network, a point I will return to shortly.

Self-Sufficiency in Technical Knowledge

Beyond freer flows of technology and the growing integration of the world economy lies another new reality. It is easier to buy technology, but the quite literal explosion in scientific knowledge and technical know-how has made it far more difficult for a private company to be self-sufficient. Even big companies with large R&D organizations find themselves going outside for help, as IBM's product strategy in small computers illustrates so strikingly. American firms are negotiating many more joint ventures and two-way technology exchange agreements. While the United States still exports far more technical knowledge than it imports, the ratio is shifting.

Needless to say, many of the larger American corporations remain world leaders in technology. Smaller U.S. firms may be leaders where they have chosen to concentrate their resources -- e.g., in biotechnology or computer software. At the same time, the domestic economy includes tens of thousands of companies with limited technical and human resources. Many of these firms must work continuously to find market opportunities which match their capabilities. Sometimes they see gaps in the marketplace they cannot fill because of a lack of people with the right kind of technical skills. Other times they may fail, for similar reasons, to recognize opportunities they might have taken advantage of. Such companies cannot hope to keep up with advances in technology and science across a broad front. Often they have trouble keeping up even in fields directly related to their current lines of business. Many stay so busy getting this year's products out the door, and designing next year's offerings, that they perform little or no R&D beyond their immediate needs. This is one reason high-technology electronics companies have banded together to form consortia like Microelectronics & Computer Technologies Corporation and the Semiconductor Research Corporation.

Institutional innovations in the private sector, of which these consortia are examples, are an encouraging response to the need for new approaches to technology development and diffusion. American firms in highly competitive industries seldom cooperate unless the pressures are great. OTA's assessments suggest there is a place for institutional innnovation within the Federal Government and among government, industry, and the academic community as well; that is innovation aimed at strengthening the infrastructure for commercial technologies. That infrastructure is relatively weak in a surprising number of important technologies. Positive action by the Federal Government could help maximize private sector initiatives, add to the many social benefits commonly associated with technological innovation and, by helping U.S. firms compete, keep Americans at work.

The Federal Role

What might these Government actions be? First and foremost, OTA's analysis points to a need for greater -- and more focused -- support for engineering research. H.R. 4047 and H.R. 4415 would provide for this in the case of manufacturing technologies.

More broadly, other pieces of proposed legislation would transfer to a new Federal agency -- perhaps, a National Technology Foundation -- the responsibility for engineering research now lodged in the National Science Foundation. OTA has discussed the pros and cons of such an approach in its Staff Memorandum on commercial technologies. In essence, we share the widespread doubt that the National Science Foundation, as presently structured, will give substantially higher priorities to engineering research. Unless a restructured NSF were provided the resources to raise these priorities, a new agency may be required.

Even if industrial R&D were to find a home in a restructured NSF or a newly created technology agency, it is not enough to have knowledge and technologies on the shelf; they must be used. Diffusing a technology base to industry is just as important as developing this base in the first place -- and may be more difficult.

The source of the difficulty is this: technology transfer is not a glamorous or prestigious activity. It will not automatically attract talented and motivated people. No one person is likely to have great impact, the way creative a engineer or scientist who designs computers or studies DNA can. It will take technology diffusion networks which outlive their members to make this part of the system function effectively, but as OTA has outlined in its Staff Memorandum, a network of loosely coupled centers, operating semi-autonomously and charged with development as well as diffusion of commercial technologies, could pay real dividends over the longer term.

Such centers would need Federal funds on a continuing basis. This is necessary to extend their time horizons beyond those of private industry. If too heavily dependent on private dollars, the centers will inevitably emphasize work aimed at relatively short-term problems -- tendencies visible in projects undertaken by existing industry consortia. These short-term perspectives contribute to the gaps in the nation's technological infrastructure. This is not necessarily to criticize industry; funcing decisions reflect the incentives and rewards corporations face. To fill the gaps and extend R&D time horizons, the Federal Government might need to provide on a continuing basis perhaps 30 to 40 percent of the total budget for technology centers. This is a major point of difference with the Stevenson-Wydler Act, which envisions a network of centers that, as they mature, would become independent of Federal support. While attractive from the standpoint of the Federal budget, such an approach might not achieve its objectives.

MANUFACTURING TECHNOLOGIES

OTA's studies point to particular needs in manufacturing. In the future, computer-based systems will help us link design and development more closely to production. At present, these activities tend to be separate from one another, particularly in larger companies and in mass production industries.

Integrating Design and Production

Little more than a hundred years ago, the technologies of most manufacturing industries remained the province of craftsmen and artisans. The people who designed tableware or steam engines or bicycles also supervised their manufacture. A single person could, in principle, design a product and build it -- or design a product and detail the production methods for others to follow, perhaps even design the rolling mills, lathes, and forging hammers needed. This same person might also be responsible for marketing.

Design and manufacturing could be linked in one man's head. As late as the 1920s, Henry Ford tried to operate this way. Yet Ford was a throwback. With mechanically-based technologies growing more complex, and production scales expanding, the scope of operations quickly exceeded the grasp of any one person. A group, many of them now academically-trained rather than self-taught engineers, now designed and developed the product -- be it an automobile, a sewing machine, one of the new plastics. A separate group, many of them also engineers, laid out the factories, specified the manufacturing operations, supervised the growing numbers of production employees. Outside suppliers often built specialized machines and equipment. Integration became an organizational rather than an individual task.

Today, we are seeing the re-integration of design and production. If one person can no longer hold in their head and in their filing cabinet the information needed for an integrated system of product design, development, and manufacturing, the computer gives us a tool that can, at least in theory, do something similar. Is this important? Very much so. Computer-based systems promise dramatic improvements in efficiency, and hence in competitiveness. The firms, and the nations, that do the quickest and best job of mastering this new technology -- a technology quite unlike most existing product or process technologies -- will find themselves atop the global economic pyramid.

The Technology of Production Systems

The problems of organizing and managing a manufacturing company differ from industry to industry and firm to firm, but they are problems of technology just as much as the development of dry etching processes for making silicon integrated circuits or the design of a new jetliner. When analyzing competitiveness, it is relatively easy to compare discrete "pieces" of technology -- components and subsystems, manufacturing equipment or end products. It is much more difficult to analyze the system as a whole. We can evaluate the products of American companies -- chips, airplanes, machine tools. We can compare them to the products of foreign industries and project the consequences in terms of future competitive trends. But neither end products nor overall corporate performance as measured by criteria such as profitability or market share give a very full picture. Nevertheless, OTA's studies of competitiveness demonstrate that the technology of production systems, considered as systems, is just as important for competitive success as product technologies or the mastery of individual process steps.

An Example from the Semiconductor Industry

In microelectronics, product and process know-how are closely tied. But there is more to their inter-relations than the ability simply to make a chip once it has been designed. Costs depend on yields -- the fraction of functional chips produced. Quality is related but distinct -- a statistical measure of the extent to which the output of the production process meets specifications. Both yield and quality depend on the design of the chip as well as control of the manufacturing process.

As in many other industries, Japanese companies made high quality (and high reliability) a central element in export strategies for integrated circuits. (The full story can be found in OTA's report International Competitiveness in Electronics.) This stress on quality helped Japanese companies penetrate U.S. markets for several kinds of memory chips. By 1981, even the executives of many American semiconductor firms were willing to admit that their Japanese rivals were delivering fewer bad chips.

What does it take to achieve high quality in the production of integrated circuits? Certainly it takes good manufacturing equipment. At the time, Japanese semiconductor manufacturers purchased most of their equipment from the same vendors that supplied the U.S. industry. These vendors -- American companies making automatic circuit testers, furnaces and etching systems, lithographic equipment -- sell all over the world. In other words, the Japanese had no advantage in the equipment on their factory floors.

The design of a product -- whether an integrated circuit or an automobile -- also affects quality. Microelectronic devices can be functionally identical yet differ in a multitude of design details. These will influence yields, quality, reliability. For products of many types, not just semiconductors, half or more of all quality and reliability problems can often be traced to the design and development process rather than to manufacturing and quality control. Memory chips, for instance, are susceptible to "soft" or non-repeatable errors caused by alpha particles emitted from trace-level impurities in the packaging. While the alpha radiation cannot be eliminated, soft errors can be reduced to tolerable levels through a variety of circuit design techniques. In at least some cases, Japanese companies implemented these techniques before American firms.

All other things equal -- the factory, its equipment, the product design -- people determine quality. But more than people as individuals, it is the system within which they work that makes the difference -- not a new lesson, but certainly one the Japanese semiconductor industry has demonstrated.

Production Systems and Computers

An integrated production system implies integrating design and manufacturing. It also implies, or should imply, integrating people more effectively into manufacturing organizations. Both aspects -- successful integration of design and manufacturing, successful integration of people and machines -- affect the competitiveness of firms and industries. Both are vital for the future of the manufacturing sector of the U.S. economy.

There is nothing new in viewing manufacturing organizations as integrated systems. By the late 1920s, Ford's River Rouge plant was operating with a high level of integration under one roof. Modern versions can be found in Toyota's much-heralded "kanban" approach, or the new Buick City complex going up in Flint.

What is new is the computer, with its potential for taking over the work now done by hundreds and thousands of people -- people whose job it has been to keep the system functioning more-or-less smoothly. These are not all production workers, although direct labor hours per unit of output in U.S. manufacturing will continue to drop. Nevertheless, people will keep on doing jobs that machines cannot perform as well -- whether in assembly, machine set-up, inspection, maintenance or repair. At the same time, large numbers of jobs associated with the logistics and control of the production process will disappear, indeed have already disappeared.

Why is this so? Because in batch manufacturing half or more of the costs go toward managing the flow of production, and perhaps three-quarters of U.S. manufacturing consists of batch production (rather than mass production, as in an automobile factory, or continuous processing, as in many chemical plants). Computers will take over more and more of the responsibility for logistics and control in factory production.

As a system, even a simple factory is complex and messy. At any point in time, a batch production shop will have a string of jobs in process. The lot sizes will differ, along with material requirements. The shop will have another queue of jobs waiting to enter the process flow. It will have a certain stock of production equipment -- e.g., machine tools. The capabilities of many of these pieces of equipment will overlap. Those that can, in principle, do the same job will nonetheless produce parts that are qualitatively different (a milled surface versus that produced by a shaper or a surface grinder). Some machines will need more highly skilled operators than others; some may be numerically-controlled, other manually operated. Costs will differ depending on the machines used. The shop can subcontract some of its work -- and may have to for specialized operations (heat treatment, plating, electron-beam welding). Add such factors as equipment breakdowns and late deliveries of materials and supplies. The result is the factory as a system -- except for the people. Add these, with their own behavioral characteristics, and we can begin to see why the costs of managing and controlling the process can exceed those for running the machines and fabricating the products.

Given this messiness, it is much easier to analyze or manage subsystems -- pieces of the whole, the smaller the better -- rather than trying to work with the system as a whole. (This is the essence of scientific management. Group technology and cellular manufacturing, likewise, are attempts to break down the production process into simple and manageable entities.) But focusing on bits and pieces in isolation does not guarantee that the factory as a system will function well. Indeed, most factories do not function well, in any absolute sense.

Broadly speaking, management and control -- ensuring that equipment is available and in good repair when scheduled for use, getting the right information, now including programs for operating computerized machinery, to shopfloor personnel when they need it, seeing that the right materials, parts, tools, and supplies are in the right place at the right time -- were once tasks for people. Foremen, stockboys and middle-managers, clerks and toolroom attendents, fork-lift operators and expeditors, did this work. Computers can do many of these jobs better and cheaper.

Even so, when computers are designed into complex systems, performance seldom lives fully up to expectations. When heavily stressed, faced with unusual conditions, automated systems often fail in unexpected ways, at which point the human operators must take over. In fact, no such system can function *without* people, particularly under extreme conditions -- and even more in a factory environment, far more unpredictable than a petroleum refinery or a powerplant. Not only are people indispensable to the operation of the system, but the system exists, after all, for the benefit of people. *Integration, in the context of manufacturing systems, should therefore be viewed as the integration of people and machines*. Much more is involved in automated manufacturing than the removal of people from the system, as I hope the example from semiconductor production has made plain. This point is vital to the future competitiveness of American industry, as well as to future employment opportunities for the U.S. labor force.

FEDERAL SUPPORT FOR MANUFACTURING TECHNOLOGIES

OTA reports beginning with Technology and Steel Industry Competitiveness, published in 1980, point to a set of problems in American industry many of which can be traced to production systems. The United States has failed to aggressively support the technical base for manufacturing, diffuse new developments to industry, and invest in the capital equipment and human skills needed to implement new manufacturing methods. Government R&D support has not only been low, it has been spread piecemeal among agencies; defense agencies, in particular, concentrate on short-term R&D aimed at their immediate needs. Industrial support has followed similar patterns.

Funding

The National Science Foundation's Production Research Program will spend $4.6 million in fiscal 1984. This Program accounts for at least half of NSF's total spending on research related to manufacturing. Among civilian agencies, the National Bureau of Standards and the National Aeronautics and Space Administration also sponsor modest levels of manufacturing R&D. The civilian total does not reach $20 million per year. While the Department of Defense will spend well over $200 million during 1984 for R&D related to manufacturing, much of this is mission-oriented; a good deal goes towards exotic aerospace technologies with limited applications in commercial industries.

As OTA has stressed in the past, priorities for commercially-oriented R&D have been low in the United States compared to nations like Japan and West Germany. As the funding patterns outlined above show, the nation's priorities for R&D in manufacturing have been low even compared to other categories of commercial technology development. The funding levels in H.R. 4047 or H.R. 4415 would, during their first year, double or triple Federal support from civilian sources for manufacturing-related R&D.

Hardware and Software

Most of the Federal Government's past and present support for manufacturing technologies has gone toward the hardware problems of making individual piece-parts rather than the software problems of system design and control. Hardware problems can be attacked through relatively conventional technology development -- engineering research into material behavior during deformation processing, improved production equipment, product designs that are easier or cheaper to make.

Software problems demand a different class of response. They involve people, organizations, institutions. Mathematical modeling, quantification, experimentation -- all are more difficult, more expensive. But often the greatest gains lie in finding workable solutions to these messy and difficult problems.

This is not to say that hardware is unimportant. Today, technologies for more-or-less conventional metalworking -- casting, forming, cutting, joining and fabricating -- remain foundations for much of U.S. industry. Heat-treating cycles that minimize energy consumption can cut production costs; so can leaner, hence less expensive alloys, or robots that waste less of the paint they spray. In many cases, knowledge that would help engineers improve even quite conventional processes is lacking -- for example, data on the plastic deformation behavior of common engineering alloys at cold- and warm-working temperatures. Higher levels of Federal R&D funding, and a central focus for Government support, could raise priorities for generic research underlying many of the most widely-used metalworking manufacturing processes. H.R. 4047, the Robotics and Automated Manufacturing Systems Research and Education Act of 1983, would have this effect to a limited extent. H.R. 4415, the Manufacturing Sciences and Technology Research and Development Act of 1983, could exert a much more powerful stimulus. Either bill, but particularly H.R. 4415, would help the long-run competitive ability of U.S. firms engaged in metalworking manufacturing.

In the future, newer production processes will have far-reaching impacts on productivity and competitiveness. Some will be improvements on relatively conventional technologies -- near net-shape processing, linking automated machine tools linked to create flexible manufacturing systems, better methods for fabricating composite materials. New processes will also be needed to take advantage of new materials -- not only composites, but ceramics and monolithic polymers. Today, some of these materials can be worked only at great expense. For others, useful properties will depend on better process control; this is case for structural ceramics, with their inherently brittle behavior. Practical production processes for new materials would contribute directly to advantages in international competition. Again, H.R. 4415, the broader of the two bills, would be more likely to help U.S. industry achieve such outcomes.

Still, the greatest gains over the next two or three decades will come from reorganizing the production system as a whole, whether or not this is coupled with new hardware technologies. Computer-integrated manufacturing has become the catch-phrase, sometimes seeming to imply getting the people out of the system because they are sloppy, unpredictable, inefficient. But as I pointed out above, it makes more sense to view integrated production systems as integrating people and machines. Improving the efficiency of such systems will take more than user-friendly computer programs or well-designed instrument and control panels, common data bases or far-flung management information systems. It will take a better sense of how to allocate tasks and responsibility among people and their machines.

Current R&D Directions

Most manufacturing research focuses on components and subsystems rather than the production system as a whole. This is as true for developments in master production scheduling as it is for R&D on robots. While both H.R. 4047 and H.R. 4415 emphasize systems integration, they might do so even more strongly.

In the United States, robotics research has centered on such problems as manipulator design and control, sensing, particularly vision systems, and the design of end-effectors (robot hands). We know little about how to integrate robots into factory environments beyond the obvious -- replace a man or woman with a machine. This is one reason most robots have been installed in assembly line or loading/unloading applications. Here the inherent flexibility of the robot seldom comes into play. Instead, the robot serves as a kind of universal machine, often replacing special-purpose machines as in many spot-welding installations. Of course, this will change as the technology progresses and experience accumulates. But even today, much of the R&D in robotics -- as in group technology or machining cells -- seems aimed at breaking down and simplifying manufacturing. Relatively little goes toward learning to put these building blocks together.

OTA assessments indicate that research agendas in other countries often place greater stress on system integration. This has been a major thrust of joint government-industry R&D in Japan. In addition, the leasing program run by JAROL (Japan Robot Leasing Company, Ltd.) seems pointed in considerable measure at the need to learn to use robots. Although both H.R. 4047 and H.R. 4415 stress applications of automated production equipment, they could be strengthened by even greater emphasis on applications and diffusion. A good deal of trial and error is inevitable in learning processes such as these; Federal support could help spread the risks.

FURTHER COMMENTS ON H.R. 4047 AND H.R. 4415

As I trust my comments thus far have demonstrated, these bills could be significant steps toward raising priorities in the United States for manufacturing technologies. H.R. 4047 is the narrower of the two, focusing largely on computer-integrated manufacturing. Building on the framework of the Stevenson-Wydler Act, the bill would create a relatively coherent program of R&D, education and training, and technology transfer to the private sector. It stresses many of the human factors and system integration aspects I've touched on above. Relative to existing funding levels, H.R. 4047 would provide substantial increases.

The range of manufacturing technologies eligible for R&D funding under H.R. 4415 is considerably broader. In general, however, the mechanisms for support spelled out in H.R. 4047 appear preferable.

Under H.R. 4415, for example, the Secretary of Commerce, through the Office of the Assistant Secretary for Productivity, Technology and Innovation, would be given responsibility for grant funding of research projects plus the option of establishing cooperative R&D programs. The Department of Commerce, outside of the National Bureau of Standards, has little expertise in technology and little experience in operating competitive R&D programs. H.R. 4047, in contrast, not only provides for an external program review board, but would give most of the funding authority to the National Science Foundation. While we have reservations concerning NSF's past support for technology development, most of these concern priorities and funding levels. By raising priorities for manufacturing within NSF, H.R. 4047 would avoid at least some of these problems.

The best prospects for strengthening the long-run competitiveness of U.S. manufacturing industries might come from combining the breadth of H.R. 4415 with the implementation mechanisms in H.R. 4047. The objective could be a etwork of technology development and diffusion centers, focused on manufacturing and following the Stevenson-Wydler model, though eligible for continuing Federal funding. Most simply, this could be accomplished by incorporating the list of manufacturing processes and methods which appears in Sec. 5 (a) of H.R. 4415 into H.R. 4047, with minimal changes otherwise to the latter.

CONCLUDING REMARKS

It is too early to tell what coming generations of integrated production systems will look like, how they will perform, in which industries they will have their greatest impacts. It is not too early to say that computerized design and production will profoundly affect the nature of work, the structure of organizations, and the international competitiveness of American industries.

In real time, changes in product design, in factory organization and work methods, in labor productivity, may seem slow and incremental. This has been the case, for instance, in color television manufacturing, hardly noted for technological dynamism. Yet in the United States, annual output per production worker went from 150 TVs in 1971 to 560 in 1981. Over this period, domestic output doubled. The percentage of value added in the United States fell, as more parts and subassemblies were imported. Domestic employment dropped by half -- partly as a result of automation, partly as a result of foreign value-added, partly as a result of redesigned TVs with fewer parts and less need for assembly labor. The example is not atypical: only by looking at the entire system can we grasp the full range of causes and consequences of technological change.

In many other industries, the changes to come will be greater. Given a world economy with a huge excess of labor, mostly in lesser-developed countries with low wages and living standards, the United States has no option but to rely on its technological resources to remain competitive. We will have to do this while finding ways to meet people's desires for satisfying work and the living standards that Americans now expect. In the end, our society may find itself inventing new kinds of production systems not only in the name of efficiency but to help give structure and satisfaction to people's lives.

Two or three decades from now, looking back, we will see that the changes in our manufacturing sector have, in total, been sweeping, that our economy has been transformed. The factory of the future will be visible only with hindsight. Such is the context within which H.R. 4047 and H.R. 4415 should be viewed.

Attachment

Excerpts from Findings, pages 5-11, in "Development and Diffusion of Commercial Technologies: Should the Federal Government Redefine Its Role?" Staff Memorandum, Industry, Technology, and Employment Program, Office of Technology Assessment, March 1984.

The Existing System

1. When Government is the end user of new technology, as is the case for military systems, Federal support for R&D is relatively straightforward. When the primary objective is commercial technology development, the Federal Government has a relatively narrow range of experience to draw on -- much of it less than successful -- and a limited array of institutions and mechanisms.

2. The United States remains without peer when it comes to science; despite the strong emphasis on military R&D sponsored by Government, few signs point to any need for major change or institutional innovation at the basic research end of the R&D spectrum. Even so, basic research that would support the international competitiveness of U.S. industries ranging from steel to automobiles to electronics has sometimes been lacking.

3. The hundreds of laboratories operated and/or funded by the Federal Government comprise a vital resource for scientific research and for the development of defense-related technologies. Even so, the National laboratories are unlikely to play more than a marginal role in the development and diffusion of commercial technologies. This has not been their mission; attempts to reorient their activities would be unlikely to have more than limited success.

4. In contrast to military R&D, where Government is the customer, direct involvement of the Federal Government in the development of commercial products and processes has not in the past fit comfortably into the U.S. political and economic system. A greater degree of such involvement might evolve over time from an approach emphasizing generic, pre-competitive technology development. However, this need not be an objective.

Commercial Technology

1. Many American companies, large and small, have ample resources and know-how to exploit technologies developed internally or acquired from other sources. Any additional support provided by the Federal Government would be useful to such companies, but is not vital.

2. Although many "high-technology" enterprises, along with firms in more traditional industries, can learn what they need to know, other American companies -- indeed, the vast majority -- are far from self-sufficient. They lack critical pieces of the technical puzzles they must solve.

3. Helping American firms acquire and make use of technology, newly developed or existing, could create new jobs and benefit the international competitiveness of U.S. industry.

4. Domestic companies could benefit from improved mechanisms for the diffusion of technology within the United States. They could also benefit from programs aimed at development of generic technologies with broad commercial relevance.

5. Initiatives in the private sector demonstrate the need for new approaches to pre-competitive R&D even among the leaders of high-technology industries. When such initiatives are funded, planned, and conducted entirely by private firms, their time horizons will not differ much from those for R&D within the companies themselves. Participation by the Federal Government could extend these time horizons to projects with longer payback periods.

The Federal Role in Development and Diffusion of Commercial Technologies

1. The Government's past attempts to develop and diffuse commercial technologies should be regarded largely as experiments -- some successful, some not. Important lessons can be learned from failures and partial failures as well as successes. A continuation of the experimental approach, one in which mistakes are both permissable and inexpensive, may be desirable.

2. Mechanisms for the development and diffusion of commercial technologies work better when flexible and decentralized. Many States already operate technology extension services, some much more highly developed than others. Emphasizing local initiatives can speed response to the needs of firms and industries in a given State or region.

3. Technologies are transferred and diffused largely by people. Technical reports, patents or licenses, conferences can all be important, but are generally only starting points. Federal support for commercial technology development and diffusion might therefore focus on building networks of technically trained people. The Federal role might encompass the following:

a) Providing on a continuing basis funds to the States earmarked for technology diffusion -- e.g., for technology extension services.

b) Funding, again on a continuing basis, for centers with missions encompassing both development and diffusion of commercially-oriented technologies.

c) The approach should be one of experimentation and adaptive learning to find mechanisms that function effectively. Some centers could be organized on a technology-specific basis. Others could be organized on an industry-specific basis.

Mr. WALGREN. Thank you very much, Dr. Alic.

You know, I just wanted to focus on, in your conclusion you're talking about the color television manufacturing effort and you're saying that output per production worker went up substantially and domestic output doubled, but the percentage of value added in the United States fell and domestic employment dropped by half. Is that inconsistent, for output to double but domestic employment drop by half? I suppose that's the leverage of automated manufacturing at that point. Is that right?

Dr. ALIC. That's right, Mr. Chairman. That is an illustration of the need to look at the system as a whole because in fact output did double, employment in the industry was cut in half, but there were multiple causes. Among those causes were greater use of imported components and subassemblies, circuit board in the TV's which came from overseas; a redesign of the television sets so that they had far fewer parts, in many cases half as many parts in 1981 as in 1971, and of course it takes less labor to assemble the set; and automation. All those things together gave us rising productivity, productivity that rose fast enough so that even though output went up, employment could be cut back, and of course that was driven by competitive pressure from the Japanese and other foreign manufacturers of televisions. That is not untypical of manufacturing industries, and I think we can expect more of that in the future. So even though output is going up, our economy is expanding, productivity must increase if we are to meet foreign competition, and the result can be labor content drops and the job opportunities in the industry are reduced along with that even though expansion is taking place. It's a very serious dilemma.

Mr. WALGREN. Mr. MacKay?

Mr. MACKAY. I can't figure out whether your paper and testimony is consistent with that of Dr. Rosenstein or whether it is inconsistent. Is it just that he has taken a longer perspective than you? Do you agree with what he said or disagree?

Dr. ALIC. I couldn't comment on his projection of 8.7 percent of the labor force being in manufacturing at the end of the century, I think, without seeing the analysis on which that's based.

Mr. MACKAY. Dr. Drucker projects a lower percentage than that but uses a slightly longer timeframe. He says 5 percent by the year——

Dr. ALIC. Yes. Well, frankly, Mr. MacKay, I have seen many of those projections myself, and I regard many of them as back-of-the-envelope calculations. The manufacturing labor force in fact, as I am sure you know, has been relatively stable over the last couple of decades. It hasn't been going up but it hasn't really been going down that rapidly either. There has been a lot of readjustment within it and the growth has been elsewhere in our labor market. The potential is there for substantial displacement and for replacement of many people with robots. With computers and other applications many white-collar jobs will disappear. If we look, for example, at the revitalization of Chrysler Corp., we see that many, many supervisory, middle management, clerical employees are gone. It's not only the production work force; it's everybody. That's what competitive pressure does. It cuts across the board.

I think we have a lot of real adjustment problems. I don't think it makes a great deal of difference whether it's 5 percent or 8.7 percent or whether we're going to stay at 17 or 20 percent. I think that the need is for mechanisms which will simultaneously help us to maintain our competitiveness in a very volatile and rapidly changing world economy, and simultaneously adjust internally to the stresses and strains that go along with that.

Mr. MacKay. All right. Then let me go at a different question. On page 3 of your testimony you have underlined:

> American industry now competes in a new international environment, a world where technology is widely available and can move easily and quickly across national boundaries. Other governments have recognized the importance of commercial technologies and design programs, often as part of more comprehensive industrial policies to strengthen the technical resources available to domestic firms. As yet, the United States has not done so.

Dr. Rosenstein also said that the thing we're failing to recognize is that technology can move across national boundaries as rapidly as capital, and he basically was saying there is a new dimension in it now. Does that render obsolete our way of thinking about technology? He was suggesting that it does.

Dr. Alic. I believe that, more than that, it has been one of the forces rendering obsolete our ways of thinking about trade policy. We have tended in the past to look at trade policy as separate from domestic economic policy and science and technology as something still different. Companies today trade technology, sell technology, with their rivals and competitors when it's to their advantage. That's the way in which international business is evolving. Companies will cooperate in some markets; they will compete in others.

There are more than 70 technology exchange agreements within the dozen or so firms in the world automobile industry today, and of course we read about that almost every day in the paper now. The same thing is happening in electronics. It will probably be happening in industries like machine tools.

I see that as part of the environment within which a policy that would support the development of manufacturing technologies would have to function. That is a reality. I agree with the several people this morning who have said that the only way to compete in a world like this is to run just as fast as you can to stay ahead. I think that's absolutely correct. That's what we have to do.

Mr. MacKay. Your other conclusion was that if we allow or require technology development to remain the sole responsibility of the private sector, that that's going to force technology development into short timeframe kinds of projects.

Dr. Alic. Yes, I think that that is the case. It has been the case. Again, let me emphasize I don't mean by that to criticize corporate management. I'm not of the school that thinks we can blame managers for the plight of American industry.

Mr. MacKay. They have got the same problem we have got.

Dr. Alic. Yes. Yes, they have, exactly.

Mr. MacKay. They are forced into a short timeframe just as Congress is forced into a short timeframe.

Dr. Alic. Yes, they are.

Mr. **MacKay**. And the accountability measures don't allow you to talk about timeframes beyond a quarterly report or the next election.

Dr. **Alic**. Yes, I agree completely, and I see one of the very valuable functions of bills like these before this subcommittee as extending those time horizons, and that is why I have suggested or OTA has suggested that there is a place for permanent Federal funding in the development of commercial technologies. That is to extend the time horizons. I don't think that Government should put in all the money. I think they should put in some fraction of the money. I think that that's necessary for stability as well, another point that has come up in several other witnesses' comments this morning, the need for stability and consistency and commitment by the Federal Government.

Mr. **MacKay**. Thank you.

Mr. **Walgren**. Thank you very much, Mr. MacKay.

Well, we do appreciate your contribution to the hearing record and your being available to the committee.

That concludes today's hearings, and I want to express my appreciation to both the witnesses and to Mr. MacKay for his interest in this subject.

[Whereupon, at 12:32 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

FEDERAL ORGANIZATION FOR TECHNOLOGICAL INNOVATION

THURSDAY, JUNE 14, 1984

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:30 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Present: Representatives Walgren, Brown, MacKay, Lundine, Gregg, Boehlert, and Skeen.

Also present: Hon. Marilyn Lloyd.

Mr. WALGREN. The subcommittee will please come to order.

Today is the fourth and final day of subcommittee hearings on the general subject of Federal Organization for Technological Innovation.

This morning we will hear witnesses' comments on the manufacturing and robotics legislation which was raised at yesterday's hearing, particularly H.R. 4415 and H.R. 4047. We also have before us legislative proposals to establish a Federal Technology Foundation which was also discussed at earlier hearings.

The basic question facing the Committee and the Congress is whether there is a role for the Federal Government in technology development. We have heard a wide range of views on this subject, ranging from the position that the Government should remain entirely passive to the view that a Federal Technology Foundation is needed with comprehensive responsibilities for at least generic technology development.

We are especially pleased to have with us this morning Senator Slade Gorton, the principal sponsor of S. 1286, entitled the Manufacturing Sciences and Technology Research and Development Act of 1984, which is the Senate counterpart of H.R. 4415, supported yesterday by Mr. Fuqua. I would certainly like to welcome the witnesses today, and particularly Senator Gorton. We appreciate your coming over and spending a little time with us. Your legislation is of real interest to us. I come from the Pittsburgh area, and the Lord knows we need help.

So, welcome to the committee. Please proceed to make whatever points you feel you would like to make. We look forward to a continuing involvement with you in the discussion surrounding this legislation.

[The prepared opening remarks of Mr. Walgren follow:]

OPENING REMARKS OF HON. DOUG WALGREN

Today is the fourth and final day of Subcommittee hearings on the Subject "Federal Organization for Technological Innovation."

This morning we will continue to review the manufacturing and Robotics legislation discussed at yesterday's hearing, namely, H.R. 4415 and H.R. 4047, and also review some of the legislative proposals to establish a federal technology foundation discussed at the earlier hearings.

The basic question facing the Committee and the Congress is whether there is a role for the Federal Government in technology development. We have heard a wide spectrum of views on this issue, ranging from the position that the Government should remain entirely passive in this area, to the view that a federal technology foundation is needed with comprehensive responsibilities for generic technology development across the board.

We are especially pleased to have with us this morning, Senator Slade Gorton, the principal sponsor of S. 1286, the Manufacturing Science and Technology Research and Development Act of 1984, which is the Senate counterpart of H.R. 4415, introduced by Mr. Fuqua.

I would like to welcome all our distinguished witnesses.

STATEMENT OF HON. SLADE GORTON, A U.S. SENATOR FROM THE STATE OF WASHINGTON

Senator GORTON. Thank you, Mr. Chairman. I want to thank you for your most gracious welcome and kind words.

I am delighted to have this opportunity to comment on H.R. 4415, a bill to establish research and development for improved manufacturing technologies. As you know and have already stated, its companion, S. 1286, passed the Senate last week.

I would also like to indicate how impressed I am with the very thorough way in which your subcommittee is examining the whole series of initiatives in this field, because this field, as you have pointed out, is so important, not just to areas like you have grown up in, but to all parts of the United States and to the future of our economy.

I know that you are aware of the factors which prompted the introduction of these bills, which will provide Federal matching funds to industry, universities, States and local governments, which are interested in pursuing research and advancing manufacturing methods as one means, one of many, of building our technological base, increasing our trained pool of engineers and scientists, and strengthening our universities. Let me set out, nevertheless, a few facts which the Senate Commerce Committee and, most particularly, my Subcommittee on Science, Technology, and Space found persuasive.

First, in 1981, manufacturing provided nearly a quarter of our national income. It accounted for more than one-fifth of all of our jobs, and it produced $154 billion in goods for export. Second, in the past 4 years, employment in manufacturing has dropped each year, from 21 million jobs in 1979 to 18 million in 1983 due to foreign imports capturing as much as 9 percent of the domestic market for manufactured goods, for example, last year. Third, in fact, the United States had a negative balance of trade in manufacturing goods exceeding $3 billion last year. Fourth, one reason for this stiff foreign competition and the apparent inability of U.S. manufacturers to meet that competition is obsolescent manufacturing methods and processes. In fact, more than one-third of the manufacturing equipments used by U.S. industry is 20 or more years old, the highest percentage of old equipment for any major, industrialized nation.

Further, to complicate the problem, our nation's universities, traditionally a major source of scientific and technological innovation, are far less involved in manufacturing than in other fields of engineering. This has been a divorce which has been long in the making and one of which we are reaping the bitter fruits now. We were able to identify only half a dozen universities with strong research and training programs in manufacturing engineering, a narrow base indeed for the extent of technological innovations needed to remain competitive.

Obviously, there are many elements in the effort to remain competitive, including the education and training of engineers, technicians, and skilled workers, and a strong technological base. The efforts of the Federal Government, of universities, and industry to enhance our manufacturing technologies and to train the associated skilled workforce have been limited and fragmented.

There is a second problem and it may be no less urgent. In recent years, manufacturing technologies have advanced through introduction of technological innovations such as the use of computer assisted design and manufacturing, automated materials handling systems, automated storage and retrieval systems, and automated sensing and testing systems. Yet, U.S. industries have been comparatively slow in adopting these innovations. It is critical to stimulate the research of more efficient manufacturing technologies, but it is also critical to encourage greater utilization of those technologies when they are available.

I believe this issue to be very important and often overlooked when universities and their role are discussed. It is not only a question of advancing the scientific and technical capabilities of our manufacturing industry, but also of having these technologies incorporated into our daily economic lives. This technology transfer is as important as creating new developments. It operationalizes and gives life to research findings. As a result, H.R. 4415 and S. 1286 have a two-tiered approach, research and utilization of research.

These bills provide support for fundamental new knowledge to underlie further advances in the field, cooperative funding for more applied work which preceeds commercialization, and experimental activities which focus on the human dimension of increased automation. These elements are appropriately backed up by an evaluative function and an external advisory committee.

One particular provision of these bills, the Centers for Manufacturing Research and Technology Utilization, are a hallmark of the legislation. In many cases, industry has the machinery and equipment and the knowledge of what it needs in technology development. At the same time, universities have the expertise, educational qualifications, and technical breadth not common to industry, but they may lack the physical resources. Certainly, where these conditions exist, there is an opportunity for a symbiotic relationship of benefit to all. In addition, the centers offer the opportunity to expose future young engineers to the importance of manufacturing engineering, traditionally a discipline less sought after within the engineering field than many others.

One final point which I would like to stress about H.R. 4415 and S. 1286, because it was emphasized to me at our 5 days of hearings across the Nation. When we speak of advanced manufacturing methods, we are not just talking about high-tech industries. The older, established industries to which you referred, Mr. Chairman, are frequently overlooked during discussions of the development of more sophisticated manufacturing techniques and devices. However, the survival of many established industries is dependent on the development, application, and implementation of state-of-the-art production technology. These industries must utilize the most modern equipment in order to survive in today's fiercely competitive international markets.

Members of the subcommittee, I believe that a critical aspect of the international economic position of the United States is its capability to maintain its leadership in manufacturing. However, to maintain that leadership, the United States must increase its scientific base for manufacturing technologies. H.R. 4415 and S. 1286 address this issue and offer one approach to maintaining U.S. leadership in manufacturing.

I would like to thank you for this opportunity to discuss these important bills with you and would answer any question or provide any assistance which may be possible for me to do.

Mr. WALGREN. Thank you very much, Senator Gorton.

My history or my involvement in this area doesn't go back that far. When I came to the Science and Technology Committee, they were well down the road on the Stevenson-Wydler Act; an act, as you know, that was almost unanimously supported in the Congress. I am trying to remember what it passed the House by, but there surely wasn't much controversy. I am sure the same was true on the Senate side. Yet, nothing seems to happen. There has been no funding of that act, in general, particularly of the centers which were designed to encourage some of the things that your university-industry centers would do.

May I ask what is your view of the reasons we run into so much resistance in this area? What is blocking us?

Senator GORTON. That is a very good question, Mr. Chairman. Some of it, obviously, originates outside of the Congress, simply a combination of inertia and desperate attempt to find ways in which to reduce budget deficits which, generally speaking, means there is an intense amount of opposition to funding any new kinds of programs.

Part of it, it seems to me, lies within the Congress itself, and the immense gulf between the positions which you and I hold working on the future, working on the authorization of programs which we feel necessary, but doing so in a way in which our companions who hold the purse strings once we have produced something of substance, play no significant role in. Maybe to a certain extent some of the fault lies with us, because we go through these hearings where we work very diligently on these problems. We triumph and celebrate when we get a law passed and signed, and then we sit back without doing as much as we ought to to see to it that they are, in fact, funded.

I might note that the administration is supporting a new set of engineering, National Science Foundation engineering centers which are really quite similar to those which are proposed in this bill. It may very well be that if we are able to authorize these, we can get the support to which we have not been accustomed from outside of the Congress for actually seeing to it that what are, after all, still abstract ideas when they are authorized become reality by being funded.

Mr. WALGREN. It does seem so sad, at least from a national interest standpoint, that we seem to be unable to react unless we really are on the verge of a real catastrophe of some kind. I know the engineering centers that the National Science Foundation is supporting at this point have really come about only because the engineering community was about to walk out of the Foundation or try to say that they felt so neglected in the overall scheme of things and the decisionmaking structure of the foundation that they felt that the engineering side was simply dying on the vine.

Senator GORTON. On reflection, you are absolutely right. We need to try, and they need to try as well, to build some outside constituencies for working on these programs to show more interest in them and more willingness to lobby for them than has been the case in the past.

Mr. WALGREN. Do you have any perspectives on how much of this balance of trade, the worsening balance of trade in manufacturing goods, is related to what may be a relatively short-term abnormal strength of the dollar versus long-term decline in our competitiveness?

Senator GORTON. That is a magnificently appropriate question, Mr. Chairman. At 10:30, I am to be back on my own side of the Capitol with the senior Senator from your State at a hearing which is entitled "Oversight on Effects of the High Value of the Dollar." It is rather interesting that you would bring that question up at this point.

However, the answer is obviously, when we look at the kinds of trade deficit with which we are faced today and even at some of the figures which I cited in my formal testimony, there are what we fervently hope to be major short-range factors which impact on them. The most significant of these is the high value of the dollar which, of course, is related to high interest rates which, in turn, is related to the huge budget deficits which we are running.

In addition to that, some of the problem is created by Third World or even second-world debt to us and demands by international banking organizations that they enhance their exporting abilities and cut back on imports. Nevertheless, having said that perhaps in a strict dollar point of view that that may be the most important single factor in our tremendous adverse balance of trade today, the challenges which we are discussing here from a long-range point of view may even be greater. We have seen so many nations in this world which were at the leading, cutting edge of technology sit back and not work to keep ahead, not work to keep at that cutting edge, cause a divorce between the academic world and the government and the private sector and find themselves on a tread mill that they simply can't get off.

I suspect, Mr. Chairman, that you and members of the committee have read some of the series of articles that have appeared very recently in the Washington Post about Western Europe and about exactly the problems it has in that respect and about its envy of our technological capabilities and willingness to do things. Well, I think in many respects those articles overstated how innovative we are, but it does show that we respect innovation. It does show that we have tried to support it, and it is much easier to meet these challenges when they are relatively minor in comparison with Western Europe by engaging in the kind of initiatives we are talking about here than it is to get ourselves into the situation of Great Britain or even West Germany or France and try to recover when you are really on the downhill slope. It is one of the reasons that this set of hearings and the sort of things we are talking about are so important.

Mr. WALGREN. Well, having a Senator here, I can't resist telling you my favorite little anecdote in this area and to encourage you, in those parts of your bill in which you evaluate in some sense the social impact of these changes. Someone once said that the only time that we went through similar changes in our economy was when we brought the tractor onto the farm and the major shift of our population went from the farms to the cities. At the same time that they did that, no one stopped to ask how many unemployed horses there were. I really think that as we go through this change I hope that at every point along the line, people like yourself and others on this side will take full account of that. Although we are very proud of the increased productivity on the farms, the major social problems that have threatened our country's well being and taken the lives of a number of people have been the social problems that arose in the center cities of the country which are largely the disregarded product of not thinking about the results of that social change.

I know that when we try to raise children now, I look back and ask myself if we had handled that change a little better, and asked about its social impact, and then taken care of some of the social impacts, maybe my children would not be as threatened by some of the dangers of growing up in our time.

Senator GORTON. You are entirely correct, Mr. Chairman.

Mr. WALGREN. So, I really want to encourage you to think of that dimension, too.

I want to recognize my colleagues and ask Mr. Lundine to take the chair, if he would, by prior arrangement, and recognize Mr. Brown for discussion.

Mr. BROWN. Senator, it is a genuine pleasure to have you here this morning and to have your legislation before us. I say that because I think you know this committee has been interested in this subject for 10 years or more. As the chairman indicated, we have wrestled with the best way to proceed to develop some sort of action in this area, going back to the passage of the Stevenson-Wydler Act. Both I and other members of the subcommittee worked with Senator Stevenson, who was your predecessor and chairman of the subcommittee on this and similar kinds of issues. We seem to have run into somewhat of a logjam. I don't think it is too difficult to perceive some of the reasons for it. We really are operating here in a hazy area of what is the proper role of the Federal Government. Obviously, this administration wants to be very cautious in moving into this area.

I think it is true that if they had wished to move aggressively, they could have implemented the Stevenson-Wydler Act and accomplished most of what your bill proposes, but that again means endorsing a broader concept than I think they wanted to endorse.

I perceive this bill that you have so carefully constructed here as being sort of a demonstration which will allow us to explore the proper role of the Federal Government in this very delicate problem of how we maintain our economic competitiveness in the world market which is the broader problem that is facing us here. I think that your initiative, the action that the Senate has taken in passing this, is an extremely hopeful sign. I wanted to indicate that to you. I think, unless we run into some partisan jealousies or something of the sort, that the House should and I hope will act promptly to pass this bill. I would like to suggest that it would be appropriate to title it as the Gorton-Fuqua Act in recognition of the two lead sponsors, and that we consider it as a prototype or a demonstration of how we can most effectively accomplish the job that needs to be done without intruding into domains that we shouldn't get into.

Let me say to you, and I will ask you to respond to this, I don't think the primary problem is going to be getting the legislation passed. I think the primary problem will be getting the Secretary and the executive level to agree that this is a useful initiative.

Let me give you an illustration of the problem there. The administration is supporting, in the Department of Agriculture, a new scientific initiative, a biotechnology program, requesting $20 million for next year, considerably larger than you are requesting for this extremely important initiative. However, they are justifying it because it is basic research. This is applied research, and the boundary line between the two is the area of difference.

In the biotechnology initiative, the results are likely to be somewhat the same as you are proposing for manufacturing. Today, the time lag between the development of a new biotechnology and its application in the field can be measured in months. There is no longer a clear distinction between the applied and the basic research in this particular area. It would take longer, because of the complexity of the problem, to actually get into the industry some of the things that we would learn in this applied research project that you are proposing. So, the time lag cannot be the distinguishing feature, and there are other kinds of similar problems.

What I am suggesting to you is that this Administration, which has been so dedicated in its support of basic research as the new biotechnology initiative illustrates, needs to have its thinking sensitized a little bit as to where the boundaries are here and what is the appropriate role. For that purpose, you are in a key position to carry to the Secretary and to the leaders in the administration this concept that this is an appropriate boundary that you are drawing and it ought to be explored.

Would you care to react to that?

Senator GORTON. Thank you very much, Mr. Brown. First, I want to say that I strongly suspect that you are right that securing the passage of a bill of this nature is going to be the easier half of the task of actually bringing it into fruition and seeing to it that something tangible happens. I think you have also put your finger on both one of the reasons for the bill and one of the reasons that this implementation may be rather difficult.

It is that it is so easy and so attractive and so with it in today's society with today's attitudes to deal with subjects like biotechnology. Anything that even has a high tech sound to it meets with a great deal of favor. Yet, one of the reasons we introduced this bill for manufacturing technologies was that it didn't have all of that romance behind it. While manufacturing technologies are very clearly what has built the United States to the point which it has reached today, it not only is it something of a stepchild of the Federal Government, but perhaps more importantly, from the perspective of this bill, it is a stepchild of the academic community as well. The hope that we could, with a modest Federal role, bring more closely together the academic community and the manufacturing community in this country to retain and regain the leadership which we have had is the basic motivation behind the drive for this bill.

It isn't going to be easy to sell the next step to the administration. All of you are very well aware of the fact that even if we pass it and authorize something for it, nothing is going to happen until we persuade our colleagues and the administration actually to fund it. However, it is an important goal, and I thank you for your complimentary remarks.

Mr. BROWN. Let me comment a little bit further. The task might not be as difficult as it appears if we get the right people to sit down and look at the right agenda. I say this because the Administration knowingly or unknowingly, already are supporting some initiatives in this area. For example, the National Bureau of Standards has a center for automated manufacturing technology. They are proceeding within their own mandate to encourage and facilitate some developments witin the industry. Likewise, the National Science Foundation is supporting some applied research in this field.

What your bill does is give it a focus, a visibility, and make it clear that this is a national priority which is not the case with these rather low-level activities that are going on at the present time. However, the difference is not one of substantial policy concern. It is one of level and visibility more than anything else. I think if the leaders in the administration become aware of this and the stature that this could contribute to our national posture, they might be willing to treat it as their response to some of this pressure to have a national industrial policy.

Our initiatives over here have suffered from being too grandiose, in most cases, because Democrats tend to feel that the role of the Federal Government is to save the world. The Republicans are more circumspect and probably are better based in trying to move more slowly in doing that. I think this is a real opportunity and I commend you for it.

Senator GORTON. I think I can do well not to respond to your last statement. [Laughter.]

Mr. LUNDINE. I ask unanimous consent that the gentleman be allowed to revise and extend his remarks. [Laughter.]

I must say, Senator, that while I share some of my friend and distinguished colleague's points of view, I am a bit more skeptical than he is. The height of my skepticism has to do with where you select the responsibility for this function to lie in your bill. We passed the Stevenson-Wydler Act and congratulated ourselves and rubbed our hands together and said we solved that problem. We would go on to other things, but not one single thing has happened. It is lodged in the Department of Commerce. They have been actually, by that law, mandated to establish manufacturing technology centers. They have not done so.

If we pass your bill, what leads you to think that they will go ahead and do anything more than thay have done with Stevenson-Wydler?

Senator GORTON. Mr. Chairman, I have no preemptive answer to that question by any stretch of the imagination. I hope that the Secretary would do so. We have tried to work with the administration in putting this bill together and hearing from them with their testimony before the Senate on it. That is not to say by any stretch of the imagination that this is an initiative of the Secretary of Commerce or of the Administration as a whole. Perhaps the statement which Mr. Brown made may be the best answer and provide the best hope. This is, for all my pride of authorship, a modest initiative. It is not the broad scale, by any means. It is focused on one particular field. It certainly is my great hope that it will do some good. I will use such influence as I have, if the bill passes, not only to see to it that there is an appropriation for it but to see to it that it is carried out by the administration and by the Secretary of Commerce. I can't give you any guarantees on that, but it represents, in one sense, after the Stevenson bill, a second or perhaps even beyond that, a reiteration of Congress of its interest in this field. It may have some value just in that sense alone.

Mr. LUNDINE. It just occured to me, have you discussed it with anyone who is involved in the President's Commission on Industrial Competitiveness? Maybe if they would recommend this limited, modest approach, that would be helpful.

Senator GORTON. We have had staff to staff meetings on that and have discussed it at that level.

Mr. LUNDINE. Mr. Gregg?

Mr. GREGG. Thank you. Welcome, Senator, to the committee. I have always been an admirer of the Senator's, and I appreciate his coming to testify on the bill which seems to me to have some significant merit to it. I have some of the problems which Mr. Lundine mentioned. I think NSF is probably a more logical place to structure this entity. I think we would probably get more attention and it would probably be more effectively carried forward than setting it up separately or even putting it in Commerce. That would be my only comment.

It also seems that the chairman, who is not here today, is from Dartmouth. I notice the sponsor is from Dartmouth, and the Appropriation Committee chairman is from Dartmouth. I happen to represent Dartmouth. It may be a logical place for this center to be placed.

Other than that, I congratulate the Senator for coming. Thank you, Senator.

Senator GORTON. Thank you very much.

Mr. LUNDINE. Mr. Skeen?

Mr. SKEEN. I have no direct questions. I, too, want to add my welcome to the Senator. He has to put up with my Senator on the Budget Committee, I see, so you and Domenici make a pretty good pair over there. I do appreciate your interest in this problem. I have been a little amused at some of the comments here today. We need to become very nonpartisan, I think, when you are dealing with this kind of issue. It has been an ongoing one ever since my experience in Congress, which has been very short, but it is one that I think deserves the kind of attention that we get both from the House and from the Senate. I want to commend you on your approach, Senator.

Senator GORTON. Thank you. As you know, your experience and my experience have been identical in length at this point, but I can say, as you have, that there has been no slate with partisanship with this particular subject in the Senate either, and I am most encouraged by the response I have had here this morning.

Mr. SKEEN. I enjoyed Mr. Brown's endorsement, and Mr. Lundine's expectation that the wonderful things we do here in Congress, once we plant that seed, no matter what kind of soil, sometimes very sterile, that we ought to stand back and let it grow. Sometimes it just doesn't happen that way, but I enjoy his enthusiasm.

Thank you, Mr. Chairman.

Mr. LUNDINE. Mrs. Lloyd, do you have any questions?

Mrs. LLOYD. I have no questions, Mr. Chairman.

Mr. LUNDINE. Thank you very much, Senator. We deeply appreciate your leadership. My skepticism has nothing to do with your vision or your conceptualization of it. We appreciate your coming.

Senator GORTON. Mr. Chairman, I am pleased to have been with you this morning.

Mr. LUNDINE. The next witness will be Mr. William Carpenter, and I would like to call on our colleague, Mrs. Lloyd, who I think would like to introduce him.

Mrs. LLOYD. Thank you, Mr. Chairman. I certainly would like to introduce Mr. Carpenter today. At the outset, let me explain that when I leave at the end of this introduction, it is not because of a lack of respect for Mr. Carpenter, but I have to appear before the Public Works Committee to testify on my bill to name the Department of Energy building in Oak Ridge after the late Congressman Joe Evans which we are also concerned about.

We are happy to be here. I appreciate your invitation to participate today by introducing Mr. Carpenter who is the vice president for Technology Applications of Martin-Marietta Energy Systems, Inc. As you know, Mr. Chairman, the Martin-Marietta Energy Systems took over the operation of the Oak Ridge facilities earlier this year. I might add my personal perspective that the winds of change have been blowing through the hills of eastern Tennessee in a most refreshing manner ever since. From what I have seen so far in terms of the Martin-Marietta approach, I hope this will be the first appearance in a series of Martin personnel providing the committee with a variety of perspectives on technology transfer requirements between the Federal Government and industry. Mr. Carpenter's insights are certainly valuable, and without preempting his testimony, I would like to call the attention of the subcommittee members to two very important points in his statement.

He points out that the U.S. manufacturing industry constitutes two-thirds of the real wealth-creating sector of the economy. The other major elements of this sector are agriculture and construction. Secondly, he emphasized the national security implications providing some short-term production for the U.S. machine tool industry. I am keenly aware of this compelling argument from my duties on the Armed Services Committee and its technology transfer panel.

I am also pleased to note that in Mr. Carpenter's discussion of the major requirements for manufacturing centers he notes, "An appreciation for quality must be embedded in all stages of manufacturing as well as in the final production." I believe that is a succinct message that must be delivered to every corner of American industry. It is not enough, in our competition with the Japanese, for instance, to say remember Pearl Harbor, as is thematic of some well-intended but potentially counterproductive legislation. Neither is it useful to dwell on the unfair advantages which they apparently enjoy through MITI or other aspects of their government-industry cooperation.

I would also urge the members of the subcommittee to learn more about the Martin-Marietta initiative in manufacturing systems engineering with the Oak Ridge National Laboratory and the University of Tennessee. I believe that this initiative and its potential fruits should be a stimulus for going ahead with a distinguished engineers program between the Oak Ridge contractor and the university system. I know that other entities with a major technological stake in Tennessee, such as TVA, are viewing these developments with keen interest.

Mr. Carpenter has 13 years of experience with Martin-Marietta and was a principal contributor in Martin-Marietta's successful competition for the DOE facilities management program at Oak Ridge. Mr. Carpenter, from your background, I can see that you are extremely well suited to provide us with a very valuable perspective on technology transfer aspects of robotics and related technologies. It is a pleasure to have the opportunity to introduce you today, and I want to thank you, Mr. Chairman, for allowing me this privilege.

Mr. LUNDINE. Thank you, Mrs. Lloyd.

Mr. Carpenter, we have your written statement. It will be made a part of the record in its entirety. You may proceed as you wish.

STATEMENT OF WILLIAM CARPENTER, VICE PRESIDENT, TECHNOLOGY APPLICATION, MARTIN-MARIETTA ENERGY SYSTEMS, INC.

Mr. CARPENTER. Thank you very much, Mr. Chairman, and thank you, Mrs. Lloyd, for your kind introduction. You have made so well some of the points that I have included in my written testimony.

Mr. Chairman, I have brought with me this morning two gentlemen who bring special expertise to the subject of our discussion.

On my right is Dr. Douglass of Martin-Marietta who is one of leading corporate experts on manufacturing technology. On my left is some little evidence that the divorce that Senator Gorton referred to is not complete. I have Dr. Snyder from the University of Tennessee in Knoxville. We have been wroking, as a corporation, very closely with the University of Tennessee, as Mrs. Lloyd indicated, in the preliminary planning of the manufacturing systems engineering center which is very similar in scope and intent to those that would be encouraged and established by the legislation that you are considering.

The nature of my discussion today, Mr. Chairman, will be primarily to summarize some of the points included in my written testimony and to supplement them.

The character of Martin-Marietta Corp. has long centered around manufacturing concerns. A great deal of our corporate activity derives from manufacturing technology of the highest state of the art. Much of our corporate activity is involved in low volume production of aerospace systems.

We are finding, particularly within the last 5 years or the last 10 years that the environmental requirements and the operational requirements associated with the systems that we are producing present as much risk in our ability to manufacture them as they do our ability to develop them. So, our interest as a corporation in the concerns that you are considering is compelling indeed.

Mrs. Lloyd referred to our rather recent involvement in the Department of Energy wherein we operate the four plants for DOE located in Oak Ridge and Paducah. One of those plants, the largest of the four, is the Oak Ridge Y-12 weapons plant. It is the primary mission of that plant to produce components for our nuclear weapons. It is involved in very highly specialized manufacturing and machining operations and has, since its very inception, been involved in leading state of the art issues in manufacturing. That is what has particularly driven our corporate interest in the bills that you are considering.

We have observed much of the other testimony that has been presented to you, sir. We find that there has been great outside authority associated with establishing the position and the conviction that we as a nation have indeed lost our lead and lost our head in manufacturing technology. We certainly concur with that conviction. Fortunately, this change in world leadership has not yet been fully reflected in a decline in percentage of GNP that manufacturing contributes. We still contribute fully very close to 24 percent, or a quarter of our total GNP from the manufacturing sector.

I personally take little comfort in the fact that we have been able to retain that 24 percent at a relatively stable level to date. The reason for that is that the important predictors would tell us that that will not continue. I would cite simply two, sir. The unit labor costs in the United States are increasing. Among the six leading industrialized nations in the western world, we are fifth, next to the highest, in unit labor costs. Indeed, our trend continues upward. The only one that currently has a higher labor cost is the United Kingdom. Their trend is downward. So, we face the bleak prospect othat we will, in the very near term, become or perhaps we already have become the free world's highest unit labor cost producer

There is a second equally distressing trend. I refer to our Nation's productivity. Again, compared to those same six countries, we are the fifth. We are next to lowest in productivity among the other six countries.

The trends in both of these, unit direct labor costs and productivity, are not encouraging at all. There seem to be no forces at play that will se to an improvement of either one of those. This would lead us to a conclusion that within the United States we have a challenge indeed if we are to retain manufacturing as a constant percent of our current GNP. The prospects are not as encouraging that. The prospects are that manufacturing as a segment of our GNP will indeed decline.

There is another point that Congresswoman Lloyd touched upon in her introduction, and I think it is a point that often escapes our attention. That is it is our belief, it is my belief, and there is some external authority for it, that the contribution of the manufacturing sector to our GNP is indeed much more important than the 24-percent figure would indicate in that it is one of the very few sectors within our GNP industries that contribute real wealth to the nation. If one goes along with the proposition that only manufacturing in the extractive industries indeed create real, tangible wealth and that the other sectors of the GNP basically derive benefit from these more basic sectors, then one can conclude that manufacturing contributes as much as 65 percent of the real wealth of our Nation as opposed to the apparent 24 percent of the GNP. Thus, the economic impact indeed is great to our nation, and the issues, therefore, that this subcommittee is considering are of great portent to our future.

There is a second point, indeed, that perhaps shares in importance with the economic importance of the manufacturing sector, and that is the point of the implications, the rather ominous implications, to our national security that a decline in the manufacturing sector would present. On this particular point, I would like to reference and endorse the testimony which Henry Sharpe, chairman of the board of Brown and Sharpe, offered to the House Committee on Antitrust and Restraint of Trade Activities affecting small business. That testimony, offered only recently, March 23 of 1984. I think his arguments are indeed compelling, should be taken seriously by us all, and we as a company certainly support that second important aspect of the concerns about the manufacturing sector to the health of our Nation.

The more direct question, I believe, on the mind today of this subcommittee, however, is not so much the importance or the relevance of the problem, because we can quickly agree on that. To what extent is the solution to the problem properly a Government responsibility? I think that is more to the point of controversy here.

We see no alternative mechanism either at play nor do we see the prospect that a mechanism will emerge to solve this large problem we confront in the manufacturing technology world. It will apparently not occur from the private industry. It will apparently not occur from the university world. We are, of course, talking about a problem that is national in scope, national in importance. I would like to distinguish, though, between the makeup of the manufacturing industry and certain other large contributors to our industrial world in the United States.

If we were talking about a problem in the world of electronics, we might well depend on private industry for its solution. If we were talking about a problem in the computer world or even to some extent in other large basic industries like steel and automotive, we could then count on, because those industries are predominated by a few large suppliers, we could count on industry being more able to meet their responsibilities for private research and development to meet the needs.

The characteristics, indeed, of the manufacturing industry are quite different. The propects for private solutions to this problem are not nearly as likely. I would like to observe that 75 percent of all U.S. trade in manufactured goods is in the low and middle volume discreet parts portion of the industry. Seventy-five percent of that important portion of the manufacturing industry, these firms, 85 percent of these firms employ fewer than 50 people. So, you are not talking about an industry where you have a few substantial corporate citizens which predominate the industry. It is a far flung network of basic discreet parts suppliers which individually are not able to undertake the vast kind of research and development that we are talking about here that we need to solve this problem that is national in scope.

So, the prospects of private solution, although I am a great admirer and our corporation vigorously pursues private research and development. The prospect of private solution of the problem that you are considering this morning is not very likely. Therefore, we think, I believe and my corporation believes, that the role of Government in undertaking realistic solutions to this problem is indeed an appropriate role and there is no apparent alternative to that.

I would like to observe that I have great sympathy for Representative Gregg's expressed position that we need to very carefully cross examine any new Government programs in the current environment that we are experiencing. We do believe, however, that the subject under discussion this morning is a logical and very compelling exception to that set of considerations.

I would like to also observe that there are particular aspects of the proposed legislation that we are particularly supportive of. We feel that not only are we talking about a very significant problem, but the provisions of the proposed legislation seem particularly effective in the solution to this problem. I would like to note two or three characteristics that make this legislation extremely practical in our view.

First of all, the emphasis of the proposed legislation is on the creation of technology. There have been authoritative studies recently completed that indicate several measures that might be entertained to improve manufacturing productivity. The creation of technology is by far the largest contributor to productivity improvement. One recently concluded study which considered such important alternative measures as capital improvement concluded that technology improvement has created 60 percent of the improvements in productivity as opposed to a much smaller 24 percent improvement by capital improvements. The point is that the legislation is working on the right part of the problem, sir, the creation of technology.

We believe also that the creation of centers which will serve as national resources is very much to the point in that again we are talking about a national problem and a few well distributed centers of manufacturing excellence which can serve as a reserve and a resource on broad based regions of geography would seem to be the vehicle of greatest benefit.

We are very sensitive as well to the problem that Chairman Walgren referred to and which has been referred to a number of times this morning and that is this problem of the ordeal involved in transferring technology from the point where it is created to the point where it can be usefully applied seems to be a particularly elusive goal for us in this Nation. We well know that some of our international competitors have fared better in this difficult process, particularly the Japanese who seem to have no market barrier between the university world or the points of technology creation and the industrial world where they can be productively used. We think that there are aspects of the proposed legislation which minimize those technology transfer problems. We particularly admire the recommendations in H.R. 4415 which would create cooperative R&D programs, because we see the result of that as being a natural partnership between the industrial user and the university world or the national laboratory world. When we get industry contributing and involved, there is a much greater likelihood, of course, that the result is going to be an applied practical result and possible for ready implementation by the industrial world. We think that what could otherwise be a very thorny problem of technology transfer is rather neatly handled in the recommended provisions of this legislation.

I would like to mention also, and Congresswoman Lloyd kindly mentioned it in her introduction, but we do have in the active planning stages between Martin-Marietta and the University of Tennessee at the Knoxville campus have preliminary plans to establish a Tennessee center for manufacturing systems engineering which, indeed, would integrate the resources of a major university; a U.S. Government production facility, and I am referring there to the DOE facilities that we operate; and national laboratory of great prestige, the Oak Ridge National Laboratory; and small and large manufacturing firms. With the nearby availability of relevant technician training, a complete range of activities in research and training in manufacturing technology we think will thus be offered. I would merely observe that the enactment and the funding of the legislation under consideration would indeed add momentum to the establishment of such a center and permit us to mature this important concept in a much earlier timeframe than would otherwise be possible.

In closing, Mr. Chairman, I would like to repeat our support of the concepts embodied in the legislation under discussion today. The need for developing and disseminating manufacturing technology is near-term and immediate. Our reasons for endorsing the

Government's support of these activities have already been stated, both here verbally and in our written testimony.

Allow me again, sir, to thank you for the opportunity to express my views on the plight and potential recovery methods of our nation's manufacturing community.

Mr. Chairman, that concludes our statement. We are available for discussion as you might wish.

[The prepared statement of Mr. Carpenter follows:]

U. S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY

HEARING ON H.R. 4047, H.R. 4415 AND S. 1286 BILLS BY THE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY JUNE 13 AND 14, 1984.

STATEMENT BY WILLIAM W. CARPENTER, VICE-PRESIDENT, TECHNOLOGY APPLICATIONS, MARTIN MARIETTA ENERGY SYSTEMS, INC., OAK RIDGE, TENNESSEE.

Mr. Chairman and members of this Subcommittee, my name is William W. Carpenter, and I am Vice-President for Technology Applications, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee. Martin Marietta Energy Systems operates four plants in Oak Ridge, Tennessee and Paducah, Kentucky as a prime contractor to the Department of Energy. One of these facilities, the Oak Ridge Y-12 Plant, has as its mission the production of nuclear weapons components, and its operations are therefore similar to those of many low-to-medium volume manufacturing plants. With the exception of the non-competitive nature of its product, this Plant is faced with exactly those challenges and opportunities in manufacturing technology that this subcommittee is considering. A second plant, the Oak Ridge National Laboratory, is charged with the generation of a broad spectrum of basic and applied knowledge, some of which bears directly on the manufacturing technology at issue here. As a government contractor we are charged not only with developing the new technology required to accomplish our mission, but also with disseminating this technology to the public whenever national security permits. This statement is offered in this dual role. I should also point out that, even though the missions of Energy Systems, Inc. are the most relevant to this hearing, my comments do reflect the point of view of the entire Martin Marietta Corporation. I appreciate the opportunity to appear before this Subcommittee hearing on a subject we feel is important to our nation's future.

The need for upgrading this nation's productive capability is indisputable at this point. I am sure this subcommittee has already been presented with not only disturbing economic statistics but also the human distress associated with the deterioration of our national competitive posture in the manufacturing arena. Because of differentials in the cost of human labor, some have suggested that the United States should focus its energies on high-technology services, rather than trying to compete internationally in the manufacturing sector. In the three decades from 1950 to 1981 the fraction of our gross national product generated by the manufacturing sector has remained essentially unchanged at approximately 24 percent. During this same period the fraction of our labor force supported by manufacturing dropped from 34 to 21 percent.[1]

Of greater significance, however, are the recent trends in international comparisons of unit labor costs and productivity indices. The divergence in productivity growths shown in these

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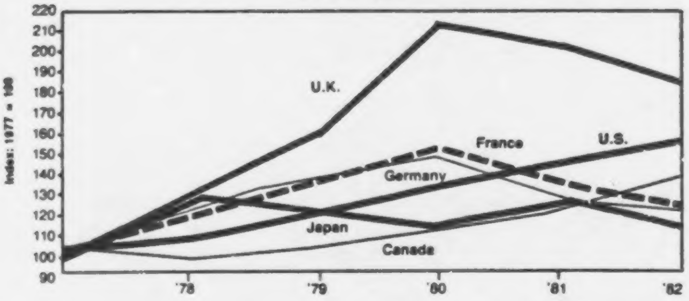
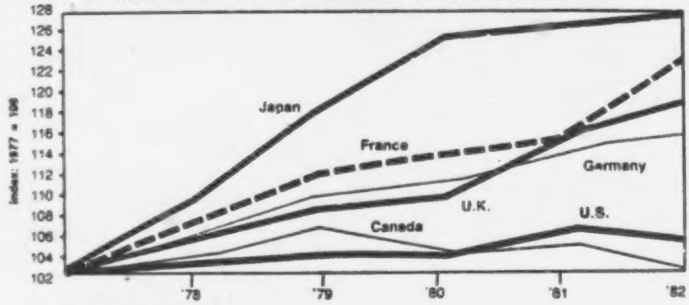
[1] Production, vol. 92, no. 1, p. 11, July 1983.

UNIT LABOR COSTS IN MANUFACTURING

U.S. Dollar Basis



PRODUCTIVITY PATTERNS IN MANUFACTURING



Source: Copeland Economics Group Inc.

charts[2] offers little consolation to the US manufacturing sector even if the present economic recovery continues. These factors, coupled with monetary policies, have led economist Michael Evans[3] to conclude "The manufacturing sector will never recover to its past days of glory, and of the 3 million jobs lost during the long recession, only 1 million will ever be reclaimed." Evans further projects that

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[2] Production, vol. 92, no.2, p.9, August 1983.

[3] Evans, Michael K., "Trade Deficits Will Force Efficiency", Los Angeles Times, vol. 102, Part IV, pp. 3-4, November 15, 1983.

1. The US economy will concentrate even more on the manufacture of high-technology products;
2. The production of basic materials will either not take place or will be highly automated with little production labor; and
3. Almost all of components of the machinery and transportation equipment will be made overseas and only assembled and marketed domestically.

One of Evans' reasons for drawing these conclusions is that overseas workers, particularly Far Eastern, have long been paid much less than US workers but previously they used inadequate and outmoded equipment. Such is no longer the case. The most disturbing element in these statistics is that the technological edge enjoyed in the past by the US has disappeared. Examples of this fact are seen in the degree of automation employed in Japanese factories, the quality of machine tools produced both in Japan and in western Europe, and the superiority of West German coordinate measuring machines.

Despite the severity of problems in the manufacturing sector, it is my opinion that the United States must regain its leadership in worldwide manufacturing competition. Dr. Eugene Merchant summarizes quite clearly the economic necessity of preserving our manufacturing industry.[4]

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[4] Merchant, M. Eugene, "Current Status of, and Potential for, Automation in the Metalworking Manufacturing Industry", _Annals of the CIRP_, vol. 32/2, pp. 519-523 (1983).

> "...the question naturally arises as to the potential of [computer automated, optimized and integrated manufacturing] to provide overall, global benefits to a country and to society in general. The answer to this question is best addressed by examining the relationship between manufacturing and a nation's economy. When this is done, one finds that manufacturing is the principle source of the primary wealth of industrialized nations, namely their real, tangible wealth. Although manufacturing accounts for about one-third of the gross national product (GNP) of the typical industrialized country today, services account for about one-half of that GNP. While services are essential to the support of a high standard of living and quality of life, they do not create primary, real, tangible wealth. Yet such wealth is the basis and source of all other wealth in a nation. Therefore, subtracting out the half of the GNP coming from services, it can be seen that manufacturing then accounts for two-thirds of the remainder -- two-thirds of the real wealth creating sector of the economy. Thus, it follows that manufacturing is responsible for about two-thirds of the primary wealth-creating activity of a typical industrialized country, the remainder coming from the extractive (agriculture, fishing and mining) industries and the construction industry."

Using GNP fractions of 63, 24 and 13 percent, respectively, for the service, manufacturing, and extraction industries, Merchant shows that manufacturing accounts for about 65 percent of the real wealth of the United States.

A second, potentially more compelling argument for maintaining our manufacturing capacity lies in the national security category. In a statement to the US House of Representatives on March 23, 1984, Mr. Henry D. Sharpe, Jr.[5] provides convincing national security reasons for short term protection of the US machine tool industry. The machine tool industry is a critical element of all manufacturing and hence warrants special consideration. Although Mr. Sharpe's statement addressed specifically the machine tool sector, many of his arguments also relate to the need for preserving the productive capacity of our manufacturing in general.

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[5] Statement by Henry D. Sharpe, Jr. Chairman, Brown & Sharpe Manufacturing Company, reprecenting the National Machine Tool Builders' Association before the Subcommittee on Antitrust and Restraint of Trade Activities Affecting Small Business. United State House of Representatives, March 23, 1984.

Crucial to the US recovery of manufacturing competitiveness is the creation and sharing of new manufacturing knowledge. McKee and Morrison[6] correlated studies by Dennison, by Kendrick, and by Christensen, Cummings, and Jorgenson on the relative contributions to productivity by labor quality, capital growth and improved technology. Averages over the three studies indicate a 59 percent contribution by technology compared with 14 percent by labor quality and 27 percent from capital. If this fact is accepted, then the question is changed from "What is necessary?" to "How to proceed?". The measures proposed in the legislation under discussion here constitute a logical approach to regaining the technological edge for the United States manufacturing industry.

The two bills, H.R. 4047 and H.R. 4415, would utilize a program of grants and a series of Manufacturing Centers as tools in generating and disseminating manufacturing technology. In our opinion these devices are effective and should be supported. The creation of new knowledge through government funded basic research grants at universities, national laboratories and nonprofit organizations has been quite successful. There is every reason to believe such fundamental studies would also be fruitful in the manufacturing field. Properly equipped and staffed, the Manufacturing Centers will function as laboratories for applied manufacturing research and development. Moreover, these Centers offer an opportunity for regional demonstrations of automated equipment and facilities to industrial firms while serving also to educate students in manufacturing technology. By providing mechanisms for cooperative funding of these Centers, the Government encourages joint industrial and academic participation which will consolidate the strengths of each. The formation of such consortia is considered highly desirable for three reasons:

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[6] Morrison, D. L. and McKee, K. E., "Technology - for Improved Productivity", Manufacturing Productivity Frontiers, vol. 2, no. 6, pp. 142-145 (June 1978). Published by Manufacturing Productivity Center, Illinois Institute of Technology Center, Chcago, Illinois.

1. The spinoff of technology to industry is enhanced.
2. University research is more likely to be relevant due to interaction with industrial partners.
3. The education of badly needed manufacturing engineers will be enhanced.

Martin Marietta is a strong believer in the private development of technology and demonstrates this philosophy through its operations. However, if the perceived need is to raise the competitive capability of the entire manufacturing industry, it is our opinion that this need will best be served by government funded, non-proprietary research with technology dissemination a primary obligation. Because of the cost of the equipment and facilities, support for a quality manufacturing laboratory will exceed the financial means of all but a few universities. A recent National Science Foundation survey quotes academic researchers as classifying one-fourth of their equipment as obsolete and out of use; 31 percent of all research equipment was over 10 years old in 1982; and only 16 percent of the equipment is state-of-the-art.[7] Very little equipment is available in universities which is dedicated to manufacturing research and development. Finally, support of the Manufacturing Centers, at least partially, by the government will encourage the participation of small manufacturing plants which play a vital role in our national manufacturing capacity.

The establishment of the National Bureau of Standards as the Federal Research Center on Robotics and Automated Manufacturing is well considered. This step has already been initiated with the Automated Manufacturing Research Facility at NBS, and the use of this facility as a technological "hub" for the other Manufacturing Centers should facilitate the dissemination of new technology. Martin Marietta Energy Systems is quite familiar with the manufacturing programs at NBS and makes frequent use of the expertise resident there.

If the Manufacturing Centers proposed in this legislation are funded, there are several factors which I feel should be emphasized in developing guidelines for the Centers.

1. Target the low-to-middle volume, discrete parts industry.

This category accounts for 75 percent of all US trade in manufactured goods. Of the firms in this industry 87 percent employ fewer than 50 people.[8]

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[7] National Science Foundation survey quoted in _Inside R & D_, May 30, 1984.

2. Computer integration of manufacturing processes should provide more opportunity for productivity improvements than the mere automation of present manufacturing actions. Examples of this are the elimination of redundant handling and alignment operations. When combined with design for automated manufacturability (including assembly), this concept will have a major impact on productivity.
3. An appreciation for quality must be imbedded in all stages of manufacturing as well as in the final product. The concept of building quality into a product or component rather than separating it out results in substantial cost savings. Furthermore, the need to tighten process control and thus improve quality should become a never ending effort. One study of automatic transmission repair histories by the Ford motor company revealed that under identical circumstances transmissions produced by an "offshore" manufacturer enjoyed a substantially lower repair rate than those from a highly regarded Ford plant.[9] Investigation showed that although the Ford-built transmissions were made to satisfy all blueprint specifications, their competitor's

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[8] Lyons, John W., Statement before the Subcommittee on Investigation and Oversight, Committee on Science and Technology, US House of Representatives, June 23, 1982.

[9] Continuous Improvement in Quality and Productivity, videotape produced by Ford Motor Company.

transmissions were made to even closer tolerances and hence assembled to a closer fit and required less repair.

4. Innovations which potentially eliminate large cost segments of a manufacturing cycle should be sought intensely. For example, a near-net shape material forming scheme which greatly reduces machining operations might save much more money than the automation of the machining operations.
5. Provide mechanisms for re-educating manufacturing personnel of all levels in the new manufacturing technology.
6. Provide manufacturing engineering consultation to regional manufacturing firms in a manner similar to the agricultural extension service.
7. Make the Center facilities available to small manufacturing concerns to allow them to test new methods for their own production needs.
8. Concepts developed in the Centers should be tested with real production parts.

A Center for Manufacturing Systems Engineering is currently under development in Tennessee. Martin Marietta Energy Systems, through the Oak Ridge Y-12 Plant and the Oak Ridge National Laboratory, is working with the University of Tennessee in evaluating this concept, and, if established, the Center will aggressively seek the participation of both small and large industrial partners. The University of Tennessee College of Engineering has been revising its curriculum for over a year. A Manufacturing Systems option will be available in the Industrial

Engineering Department for Master of Science students beginning in January 1985. Martin Marietta and the University are currently assessing the equipment required to establish a creditable Manufacturing Center as well as a suitable location. Support of the faculty release time for these activities is being provided through a $120,000 grant from the Alcoa Foundation. These assessments should be complete in early August. Funds of the type proposed under this legislation would greatly accelerate the time when the Center would become operational.

The Tennessee Center for Manufacturing Systems Engineering will take advantage of several unique factors. The proximity of the University of Tennessee and Martin Marietta Energy Systems greatly facilitates cooperation. The Oak Ridge Y-12 Plant is typical of the discrete parts industry, and the Y-12 Plant management and operating personnel understand the problems. This plant has considerable strengths in material forming, precision machining and gaging. The quality aspects of manufacturing methods are well understood. Of considerable relevance is the fact that the Y-12 Plant is currently upgrading its operations with computer integrated manufacturing methods and equipment (flexible manufacturing systems, robots, computer networks, graphic systems, etc.) of the type to be studied in the proposed Manufacturing Centers. The University of Tennessee has a faculty knowledgeable about manufacturing processes. The strength of the research and development facilities and capabilities at Oak Ridge National Laboratory are well known. Their measurements and controls experience is particularly appropriate for the development of new sensor technology required by advanced automation. Two consortia are presently being organized which relate closely with manufacturing technology. The Center for Measurement and Controls, a joint effort between the University and Oak Ridge National Laboratory, will provide for sharing of the facilities and staffs of both organizations in conducting research and teaching. A Computer Aided Engineering Consortium, a cooperative endeavor of the University, Martin Marietta Energy Systems and several other local industries, will provide training and research in problem solving using interactive computer graphics. The administration of both of these activities is deliberately being overlapped with that of the Manufacturing Center to enhance coordination.

Spinoff of unclassified technology developed at Martin Marietta is an explicit contractual obligation to the US Department of Energy. A modern Manufacturing Center would certainly enhance this activity. The University of Tennessee has a well established network through its Center for Industrial Services for providing technical assistance to small industrial firms. This activity is funded by the State as part of the public service mission of the University.

The state of Tennessee is aggressively pursuing the development of the Tennessee Technology Corridor along the parkway connecting Knoxville and Oak Ridge. A new campus for the State Technical Institute in Knoxville is being erected approximately midway between the two cities. This institute will emphasize the training of technicians in the operation and maintenance of modern manufacturing equipment.

The Tennessee Center for Manufacturing Systems Engineering will integrate the resources of a major university, a US government production facility, a national laboratory, and small and large manufacturing firms. With the nearby availability of relevent technician training, a complete range of activities in research and training in manufacturing technology will thus be offered.

In closing I would like to repeat our support for the concepts embodied in the legislation under discussion today. The need for developing and disseminating manufacturing technology is immediate, and our reasons for endorsing the government support of these activities have already been stated. Allow me again to thank you for the opportunity to express my views on the plight and potential recovery methods of our nation's manufacturing community. Mr. Chairman, that concludes my statement.

PERSONAL DATA ON W. W. (BILL) CARPENTER

Mr. W. W. (Bill) Carpenter is Vice President, Office of Technology Applications, Martin Marietta Energy Systems, Inc., Oak Ridge. The primary objectives of this office are two: (1) the successful transfer or promising technologies into the private sector, and (2) the stimulation of economic development within the Oak Ridge communities and the East Tennessee region.

Mr. Carpenter received a bachelor's degree in Industrial Management and a master's degree in Business Administration from the University of Denver.

Mr. Carpenter has 13 years experience with Martin Marietta, with successively increasing responsibilities. He most recently served three years as Business Development Director, Martin Marietta Orlando Aerospace. His duties included identification and management of Advanced Programs activity, Independent Research and Development tasks, as well as market strategy development. Mr. Carpenter was a principle contributor in Martin Marietta's successful competition for the DOE facilities management program at Oak Ridge.

Mr. Carpenter was responsible for identifying business areas for major new business thrusts for Martin Marietta. These entrepreneurial activities included, in 1982-83, major responsibilities in the identification of the Oak Ridge opportunity and the development of Martin Marietta convictions associated therewith.

Mr. LUNDINE. Thank you very much. I think it is particularly useful to have testimony from an industry such as yours that is involved in the highest level of technology, probably some of the highest level of regulatory problems, and has probably the closest contact with Government because, in many cases, the Government is also your customer.

Mr. CARPENTER. Yes, indeed.

Mr. LUNDINE. Let me just nitpick for one point. You said, I believe, that the United States has the lowest level of productivity of any of the industrialized countries. I think you meant to say the lowest rate of growth or productivity of any of the industrialized countries. I think the evidence is that we still have the highest absolute level of productivity, but our growth level is so low that clearly we are not going to sustain that position much longer. If I am incorrect on that, I would like to know about it.

Mr. CARPENTER. I believe you are correct. We are talking about, and our sources are cited in our written testimony, that is a standardized productivity patter that we are referring to there which apparently does include the effects that you are discussing.

Mr. LUNDINE. Since you have both been identified already, please feel free to comment.

Dr. SNYDER. Yes; I would like to comment on what has been referred to here as the divorce between industry and academia. Hopefully, that term is too strong. I think alienation is certainly accurate. It is a fact. It is one that I lament having happened over the past couple of decades, but I think we are at a point where we need to move away from viewing it with alarm and begin to think more positively, and let's have at it and what can be done to improve this relationship.

I think, and I have thought about this a bit in the past as to how this came about, and perhaps there is some lesson to be learned in history as to how the alienation between the academic world and the engineering world and industry came about. Perhaps there is a clue as to how to improve it in the future.

There are several factors. I think it is true that manufacturing engineering as an academic discipline has been the stepchild in academia. It has not had the glamour of the electronically oriented technologies, such as the computer based technologies. Also, I think we have been seduced into somehow thinking that all of the talk about an information based society makes it no longer necessary to worry about our base industries. I submit that we won't have an information based society unless we have some base industries to provide that technology.

A final observation, I think that perhaps if we go back to the period when I was still a student, the post-Sputnik era, which created an attitude in academia that the place to turn for support of research in universities was the Federal Government, and we went through a period in which national technological goals were pretty much set by the attitude of the Goverment in space, energy, and environment, I think are good examples, where the engineering community recognized these as national goals, and we tended to look toward the Federal Government for the support of the research in these areas.

I believe measures such as H.R. 4415 would move us forward very quickly in terms of bridging this gap between industry and the university educational community in engineering education. We have to keep in mind that our students will have 30 to 40 years of productive careers ahead of them in a future that is very much unknown except that it is going to be changing and it is going to be changing very rapidly. It is very much incumbent upon us in academia to do the best job we can of trying to project what that future is going to be like. It is extremely important that we have a close interaction with our industrial colleagues. They are the ultimate users of our products. They are our ultimate customers. I think measures such as proposed in H.R. 4415 would be very supportive of this process of bringing back together the academic world and industry. I think there is very definitely a role for the Federal Government in this process.

Mr. LUNDINE. If academia and industry have become alienated, Government and industry seem to really be alienated. I wouldn't use the term divorce, but seriously alienated, and that leads me to my question. We frequently hear critics on both sides of the aisle and representing different philosophies suggest that this is an improper role for the Federal Government because you would be picking technologies. I have heard the story so many times about Mr. Noyes' wife who asked him whether she should invest in a small computer company and being told by Mr. Noyes that a personal computer didn't make any sense and, fortunately, she disregarded his advice and invested a modest sum in Apple Computers, that if I every meet Mr. Noyes I am going to certainly ask him if it is true. It has certainly been repeated often enough so that it is legendary if not accurate.

However, the assertion is then made, well, certainly if a genius in technology can't pick a winning technology, how is the Federal Government going to do it? I would be interested in your response to that.

Mr. CARPENTER. Well, I think the result of the legislation we are talking about will not amount to that much of a predominate role by the Government itself. Now, whether the Department of Commerce ends up administering this or NSF is perhaps less important than the manner in which it is administered. Incidentally, we are meeting with the Department of Commerce people tomorrow morning to express our support for this and try to take a reading related to their sentiment. As they would make the grants or the cooperative R&D investments, personally, although there is a cost implication in terms of matching, I would tend to favor the cooperative R&D, because I think it will avoid some of the point that you are just getting at, sir. There will be, should be, in the administration of this, great latitude for freedom of innovation and related to the conduct of the activities within the centers themselves. We would depend upon that.

Of course, we are talking about the potential for an array of centers which could present the exploitation of alternative technologies. We would hope that it would. I would not share that particular concern related to this issue. Now, if you are talking about very high speed integrated circuitry or some of the electronics issues, perhaps that danger is more imminent that the Government in their role cannot avoid technology selection or technology bias. I would not see that as a jeopardy in this particular one. That is just my opinion, sir.

Dr. **Douglass**. I might add a point. I really think the involvement of the local industry with the academic community is going to keep the research directed in those directions that are most relevant.

Mr. **Lundine**. Well, I think your testimony is right on target from my point of view. I have not examined all of these bills in the detail that I will before we take action on them, but one aspect that seems terribly important to me is that they have flexibility. I learn by example better than by generality and had the opportunity not long ago to visit Battelle Institute in Columbus, which is a good example of an agency or an enterprise that is sort of in between this basic research and applied technologies. It strikes me that like that privately endowed institution, these new centers ought to be able to contract directly with a single industry if they wanted to to do some more advanced research.

On the other hand, they might be doing other research that would be generally shared with everybody because it is more generic.

Mr. **Carpenter**. Yes.

Mr. **Lundine**. Would you agree with the need for that kind of flexibility.

Mr. **Carpenter**. Yes. Yes, sir. Why not?

There has been a reassuring amount of progress in this overall environment of making even Federal laboratories more accessible to private firms on a basis that will protect the proprietary nature of the investment that the firm makes. We are familiar with the manner in which Battelle operates in the labs in the Northwest, where they are very well able to segregate between those items of national interest which we all have a right to and from national funding versus those private initiatives which Battelle conducts side by side with some of the Government initiatives, but they are able to partition those initiatives off.

Mr. **Lundine**. Another thing that I think— excuse me, I didn't mean to interrupt.

Mr. **Carpenter**. Yes.

Mr. **Lundine**. Another thing that I think might be important would be to encourage industry scientists to come into the university setting for certain periods of time to work along with people working in these centers.

Mr. **Carpenter**. Absolutely. I would make one other observation, sir, and that is in this respect that you cite, and that is why shouldn't the centers be able to receive private contract initiatives and protect the proprietary nature, in those cases, of the work that is done? To do this, we would be getting a step towards—I think we can take a lesson from the West Germans who operate their national laboratories in a very similar fashion. Much of their work is on proprietary contract with private industry. No reason we shouldn't be able to do the same thing to advantage.

Mr. **Lundine**. If we were to have, say, 10 centers, do you think we should pick one to be in one particular area and another in a different area or is that not necessary? Do you understand what I mean by an area?

Mr. **Carpenter**. Yes, sir, I do. It would seem, politics aside, that there is some basis in reason to support a distributed network from a geographic standpoint. In other words, I don't think that it would be healthy for us to dump them all in the Northeast corridor, for example, or even in the Southeast sector.

Mr. **Lundine**. Well, I was thinking more by function. I agree, and I think you can count on their being distributed. [Laughter.]

I don't know whether any will go to areas not represented on this committee or not, but they will be distributed to some degree.

What I was think of is should we have one biotechnology area, one machining center, one in metalurgy, by function or should we allow them to be broad and to get into different areas?

Dr. **Snyder**. I would like to offer a comment on that. I think certainly there has to be coordination of the centers to avoid unnecessary duplication. I think an appeal to me would be that each center would have a particular focus that would build on the strengths that that center is able to pull together because of its geographic location. That is the strategy that we are following in Tennessee in our joint effort between the Oak Ridge National Lab and the university to try to build on the strengths that exist and not try to be all things to all people. I think some of that would make sense in having each center have a particular area of focus and responsibility.

Dr. **Douglass**. Some of that is going to arise fairly naturally by the submissions of proposals and that kind of thing. I suspect that the funding source, whether it is Department of Commerce or whomever, would exercise some selection. They wouldn't want all of them to be machine tool design and construction research and none in biotech.

Mr. **Lundine**. I thank you very much, gentlemen. You have been very helpful to us. This perspective from the action level, which some people call the real world, is particularly important.

I am going to recess the hearing for about 5 minutes. We are going to return with Dr. Robert Pry's testimony in about 5 minutes. I apologize for the delay.

[Recess taken.]

Mr. **Walgren**. I apologize for the interruption. As I understand it, the next witness is Dr. Pry, the executive vice president for Research and Development at Gould, Incorporated. Welcome to the committee, Dr. Pry. Your written statement will be made part of the record, and please feel free to highlight the points you feel are most important in whatever way you feel most effective.

STATEMENT OF DR. ROBERT H. PRY, EXECUTIVE VICE PRESIDENT FOR RESEARCH AND DEVELOPMENT, GOULD, INC. (RETIRED)

Dr. **Pry**. Thank you very much. I am delighted to be once more before this committee. I have to hasten to add that I have been misrepresented in my introduction. When I was originally asked to testify, actually, on the merger of NSF and the Bureau last year, that was the initial invitation that went out to me. During that time, I was indeed vice chairman of Gould. Since that time, and it has been a year since the original request, I have retired from Gould, so I am a recently retired vice chairman of Gould, Inc., where I spent the last year, as a matter of fact, looking specifically at the whole issue of internal technologies in the company, in particular, manufacturing technologies.

I am currently an executive consultant to industry, government and universities, concentrating on ways to focus our combined technical talents and organization to improve short and long term competitiveness. Among my credentials before this committee are a number of what one might call unpaid if not uncompensated activities, including membership on the board of the National Electrical Manufacturers Association, where I suggested an initiative on automation. I am on the Energy Research Advisory Board of DOE in which capacity I have given testimony before this committee before, the Industrial Advisory Board of the National Science Foundation, the Statutory Advisory Committee of the National Bureau of Standards, and the boards of a few small technology companies, and on the advisory boards of a number of engineering schools and management schools of several universities. I am also a member if Illinois' Governor Thompson's Commission on Science and Technology, and I recently joined the staff at MIT where, among other things, I am helping them set up a program in manufacturing management between the Sloan and engineering schools and a thrust in manufacturing research and development.

It is from this background, then, that I draw my observations and comments. However, I speak obviously for myself as a concerned citizen rather than for any of these groups.

I am please to have the opportunity to join the distinguished panel of people to address these issues of Federal organization structure needed to change our technological well being and competitiveness and the specific issue of manufacturing technology.

First, I would like, as the Senator did earlier, to give a preamble to put some of these issues in context. During the last couple of years we have witnessed and been party to a debate on international competitiveness unequalled since the debates following the Sputnik launch of the late 1950's. The debate has focused upon the inroads that the Japanese and Europeans have made in our domestic markets. Recently, the reasons advanced for the decline of U.S. competitiveness abroad have been largely attributed to a perceived reduction in this Nation's technological capabilities. I would like to question the single-mindedness of that position before discussing the issues of advanced technology before the committee today.

The Nation's ability to sell its products abroad is dependent upon product price and quality, as well as other importing nation's direct and indirect constraints on free trade. Setting these contraints aside for a moment, the price of goods sold abroad is determined by both the cost of U.S. production and the value of the U.S. dollar relative to foreign currency. I suggest that a major problem in our international competitiveness is the current value of the U.S. dollar, which has increased in recent times relative to our other trading partners by 25 to 50 percent. This means, of course, that other countries can undercut the price of U.S. producers, both within the United States and internationally. This is not to suggest that productivity and quality are not issues of great significance, because they are. However, many of our short-run international trade difficulties are at least as involved with fiscal policy as with technological policy.

I bring up this point first because our near term trade problems are far more likely to be solved by addressing fiscal than by addressing technology policy. However, let me hasten to add that our long-term competitiveness internationally can only be assured by a policy aimed at reasserting technological leadership in a partnership of all our talents in the Government, industry, and university sectors.

So, in the long term, the issue before us is the appropriate role of government in assuring the health and advance of technology and technology talents in the United States. Let me begin the discussion by setting forth eight broad areas where I believe the Government has a clear role to play. These are: Education at all levels; basic and applied scientific research; engineering research in generic technologies underlying broad business segments, where little Federal effort has been expended except in the area of energy; technical information dissemination, especially to small businesses; establishment of basic standards or means of assurance of quality in commerce; performance and funding of specific areas of research relating to the nation's security, which we do a lot of, or to major national strategic objectives, where we do very little; tax and other incentives to help catalyze industry formation and growth where appropriate to the Nation's advancement; and regulation and control where needed to assure the Nation's health, safety, and welfare.

I don't believe any single agency of Government can serve in all of these areas with equal zeal and competence; nor should any try to do so. Each of these areas are so broad and so pervasive in their effect on our future that they are left to a single agency at the Nation's peril. Only by a combination of approaches can we have any assurance of making the right choices. Centralization of authority is appealing because it is neat and simple. History repeatedly has shown, however, the folly of this approach, whether in the defense or the commercial sector.

Now let me try to outline a set of principles that help me, at least, in thinking through the problem before us today.

In the area of science and technology, the critical commodity is the minds of men. In the near term, regardless of the money spent, this is, to a first approximation, a zero sum game except, of course, with respect to the need and a fairly urgent need to upgrade university engineering facilities which are woefully behind even our lagging commercial sectors. The question to address is what is the proper rebalancing of things to do, not necessarily what more should we do. Expanding the money overall in science and technology in the short term only means doing more things less well.

In the intermediate and long term, this critical commodity can be expanded through education with some pull through incentives from an economic emphasis in critical areas.

Reshuffling existing agencies and funding into different agglomerations, which has been proposed in the past, without major redirection of objectives only creates, in my view, confusion without any fundamental change.

Mixing many objectives in a single agency also tends to confuse agency purpose and decrease effectiveness in some of the functions. For example, stimulation and regulation, in DOE, and broad education and specific research and development. I think we have evidence that NSF is ripping its knickers attempting to approach that one. Intimate mixing of contracting and performing research, and I mean here intimate mixing which, in some cases, in the Government laboratories, tends to give some rather narrow mindedness in terms of what gets supported.

Lastly, creating organizations to study already well defined problems is a sure and efficient way of postponing decisionmaking.

I would like to just make one other remark before reviewing the particular bills being considered. I do firmly believe that additional and/or different initiatives are required to better stimulate engineering research and technology development in this country. As I mentioned under the first principle I mentioned above, this means arranging to better utilize existing manpower in industry, institutes, universities, and government to improve our technological base and accelerate bringing science to market with quality, economy, and safety.

The National Science Foundation, in my view, is an excellent agency for science and engineering education support and science and basic engineering research support, but fundamentally and culturally has a problem in understanding and dealing with specific engineering research, applied research, and generic technology development at a nationally meaningful level. Our defense agencies have a history of successful research and development using all sectors, industry, university, and government. Although the fallout from that work has had important nondefense consequences, its mission necessarily creates blind spots relative to national nondefense economic and related science and technology bases.

The National Bureau of Standards in the Department of Commerce, in a slightly broader context than it now has, might be described as the Nation's corporate laboratory and probably among the Nation's laboratories in the Federal sector has more interaction with industry than any other. As such, I personally believe it belongs exactly where it is. It provides a superb interaction with industry and a much needed window on technology for the Department of Commerce. I would have great concern if one turned it also into a large contract funding agency. In short, something new is needed, but what?

In my opinion, H.R. 481 has merit but is somewhat flawed by incorporating the National Bureau of Standards, the Patent and Trademark Office, and the National Technical Information Service. I personally do not see any desire or need for changing the mission of these groups. They seem to work well and already are where they belong. Rearranging money pots and people to make the effort look bigger and more coordinated rarely has a positive effect.

H.R. 1243 is, in my opinion, if taken alone, a way of postponing any positive action. It is my belief that H.R. 1243 can be accomplished within current legislation and administrative guidelines and should require really only congressional encouragement without additional legislation. Such a study indeed would be useful but not critical.

H.R. 2525 is aimed at the broad issue of a national industrial policy which has been recently debated with varying degrees of emotion and common sense. Let me start by saying that the issue is not whether or not we should have an industrial policy, for no policy or an infinite number of uncoordinated statutes and regulations dumped in a basket are already a form of industrial policy. The issue is how coordinated or at least internally consistent should that policy be. I favor the purpose addressed by this bill since it only really takes the first logical step of collecting information about how conflicting and discouraging or how coordinated and supportive are the rules and regulations we now have, taken all together. What we do with the results, in this instance, might indeed be left better to be decided until after the results are in.

The purpose of H.R. 4361 as described in sections 6 and 7 of that proposed bill are, in my opinion, laudable objectives and worthy of a more detailed examination as this bill is considered further. Rather than forming a new agency, however, it seems to me that many of its objectives already have some roots either currently or in history in the Department of Commerce. It is not clear to me why a new agency is required over a clear mandate to the Department of Commerce which now has a lean but knowledgeable staff in many areas of the bill.

I might just say parenthetically that I recently had an opportunity to talk to Secretary Baldrige in connection with the activities of the visiting committees of NBS. In my opinion, I believe that he has a better grasp on technological issues than any Secretary of Commerce, at least in my memory, and I do not believe that the problem with getting initiatives going in the Department of Commerce lies with the Secretary. I believe it, in fact, lies elsewhere. I can give you a private opinion, and that is from simply discussions with a large number of people in and outside of Government. It lies with OMB. It lies in part with the OSTP, and with the people who fundamentally come down to setting the objectives of maintaining a budget level throughout Government and the setting of priorities, which weighs itself somewhat more heavily on defense than it does in the commercial sector.

Mr. WALGREN. Fairly stated.

Dr. PRY. Incidentally, with respect to the machinations of last year with what I call doo-wah-ditty, if one really wants to look at the international effort in the Government with respect to international trade, it seems to me that there is a place where one might think of a new agency rather than tearing the Department of Commerce apart and stuffing it back together again in different ways. But I have digressed a little bit.

The bill mentions $500 million as an expenditure level. I am sure that is a fairly roundhouse figure. Nonetheless, I think it is a lot more realstic, quite frankly, than the roughly $20 to $80 million mentioned in the other bills that I talked about and will talk about shortly. To put that in context, remember that the Bureau of Standards, this last year, got roughly $115 million of direct supportive funds—they have gotten roughly another $100 million or so through other agencies, but their own budget is about $115 million—and they are considered to be only scratching the surface. I think roughly 10 percent of that, for example, is their manufacturing initiative. The administration and salaries, for example, for the Government bankruptcy courts is roughly $100 million, to look at the consequences of lack of initiative in another perspective. So, I believe that what the Government does here should be a significant effort as opposed to small catalytic efforts in a variety of specialized areas.

Having said that, however, I have to repeat again the assertion that we are dealing with a fixed number of good minds in the short run. When we spend the equivalent of $500 million worth of talent and support on this kind of generic activity, we really ought to ask what we are going to have them not work on. If we cannot find any activity of less importance to stop working on, then we ought to reexamine how important this initiative really is.

Finally, I would like to comment briefly on H.R. 4407 and H.R. 4415, the two bills that are complimentary approaches to a rather limited technology, namely, automated design, manufacturing, and testing. However, in its present form, H.R. 4047 is in fact restricted to robotics and automated manufacturing systems.

Although each of these bills has merit, and I must say I am speaking perhaps more broadly than from a selfish purpose since some of my activities at MIT are in fact to help them set up a center in these kinds of activities. Nevertheless, in my view, they are far too restricted in scope and in suggested funding. To proceed along these lines would inevitably lead, in my opinion, to an automated office bill, a bioengineering development bill, a design for manufacturing bill, and so on, in the areas of various weaknesses in our industrial complex. It just seems to me that the issue we face is an issue of policy creation for the ongoing partnership between the private and public sector for the assurance of job creation, international competitiveness, and the stimulation of the positive benefits of technology before the fact rather than government control of the negative effects of technology after the fact. If this is the case, then we should get on with drafting a comprehensive bill along the lines of H.R. 4361 rather than take a piecemeal approach.

In closing, I understand what the political problems are in getting at this kind of a comprehensive bill. On the other hand, the idea of starting a small bill with the idea that that is going to serve as an example I am afraid writes for us a timetable which is far too long to be effective in this area of supporting U.S. technology.

Thank you very much. I would be glad to answer any questions.

[The prepared statement of Dr. Pry follows:]

TESTIMONY

OF

DR. ROBERT H. PRY

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

OF THE

U.S. HOUSE OF REPRESENTATIVES

JUNE 14, 1984

Good Morning, Mr. Chairman.

My name is Robert Pry and I am recently retired Vice Chairman-Technology of Gould Inc., a 1.6 billion dollar electronics company located in Rolling Meadows, Illinois, a suburb of Chicago. I am currently an executive consultant to industry, government and universities concentrating on ways to focus our combined technical talents and organization to improve short and long term competitiveness. Among my credentials before this committee are a number of "unpaid" activities, including membership on the Board of the National Electrical Manufacturers Association, The Energy Research Advisory Board of DOE, The Industrial Advisory Board of NSF, The Statutory Advisory Committee of the National Bureau of Standards, the Boards of a few small technology companies, and on the advisory boards of engineering schools and management schools of several universities. I am also a member of Illinois' Governor Thompson's Commission on Science and Technology and I recently joined the staff of MIT.

It is from this background that I draw my observations and comments. However, I speak only for myself as a concerned citizen rather than for any of these groups.

I am pleased to have the opportunity to join the distinguished gentlemen on this panel to address the issues of the Federal organization structure needed to enhance our technological well-being and competitiveness and the specific issue of manufacturing technology.

First, a preamble to put these issues in context. During the last two years, we have witnessed and been party to a debate on international competitiveness unequalled since the debates following the Sputnik launch of the 1950's. The debate has focused upon the inroads that the Japanese and Europeans have made into our domestic markets.

Recently, the reasons advanced for the decline of U.S. competitiveness abroad have been largely attributed to a perceived reduction in this nation's technological capabilities. I would like to question the single-mindedness of this position before discussing the issues of advanced technology before the Committee today.

The nation's ability to sell its products abroad is dependent upon product price and quality, as well as other importing nations' direct and indirect constraints on free trade. Setting these constraints aside for a moment, the price of goods sold abroad is determined by both the cost of U.S. production and the value of the U.S. dollar relative to foreign currencies. I suggest that a major problem of our international competitiveness is the current value of the U.S. dollar, which has increased in recent times relative to our trading partners by 25 to 50%. This means, of course, that other countries can undercut the prices of U.S. producers both within the U.S. and internationally. This is not to suggest that productivity and quality are not issues of great significance, because they are. However, many of our short run international trade difficulties are at least as involved with fiscal policy as with technology policy.

I bring up this point first because our near term trade problems are far more likely to be solved by addressing fiscal policy than by addressing technology policy. However, let me hasten to add that our long term competitiveness internationally can only be assured by a policy aimed at reasserting technological leadership in a partnership of all our talents in government, industry and university sectors.

So, in the long term, the issue before us is the appropriate role of government in assuring the health and advance of technology and technology talents in the United States. Let me begin this discussion by setting forth eight broad areas where the Government has a clear role to play. These are:

1. Education at all levels
2. Basic and Applied Scientific Research
3. Engineering Research in Generic Technologies underlying broad business segments

4. Technical information dissemination especially to small businesses
5. Establishment of basic standards or means of assurance of quality
6. Performance and funding of specific area research relating to the nation's security or to major national strategic objectives
7. Tax and other incentives to help catalyze industry formation and growth where appropriate to the nation's advancement
8. Regulation and control where needed to assure national health, safety and welfare.

I do not believe any single agency of government can serve all of these areas with equal zeal and competence; nor should any try to do so. Each of these eight areas are so broad and so pervasive in their effect on our future that they are left to a single agency at the nation's peril. Only by a combination of approaches can we have any assurance of making the right choices. Centralization of authority is appealing because it is neat and simple. History repeatedly has shown the folly of this approach, however, whether in the defense or the commercial sector.

Now let me try to outline a set of principles that help me in thinking through the problem before us today.

1. In the area of science and technology, the critical commodity is the minds of men. In the near term, regardless of the money spent, this is a zero sum game. The question to address is what is the proper rebalancing of things to do, not what more should we do. Expanding the money overall in science and technology only means we will do more things less well.

2. In the intermediate and long term, this critical commodity can be expanded through education with some pull through incentives from economic emphasis in critical areas.

3. Reshuffling existing agencies and funding into different agglomerations without major redirection of objectives only creates confusion without any fundamental change.

4. Mixing many objectives in a single agency tends to confuse agency purpose and decreases effectiveness of some functions (e.g., stimulation and regulation; broad education and specific research and development; intimate mixing of contracting and performing research).

5. Creating organizations to study already defined problems is a sure and efficient way of postponing decision making.

I would like to make just one other remark before reviewing the particular bills being considered. I do firmly believe that additional and/or different initiatives are required to better stimulate Engineering Research and Technology Development in this country. As I mentioned under principle I above, this means arranging to better utilize existing manpower in industry, institutes, universities and government to improve our technological base and accelerate bringing science to market with quality, economy and safety.

The National Science Foundation, in my view, is an excellent agency for science and engineering education support and science research support but fundamentally and culturally has a problem in understanding and dealing with Engineering Research and Generic Technology development at a nationally meaningful level. Our defense agencies have a history of successful research and development using all sectors and, although the fallout from that work has had important non-defense consequences, its mission necessarily creates blind spots relative to the national non-defense economic and related science and technology base.

The National Bureau of Standards in the Department of Commerce might be described as the nation's corporate laboratory. As such, I believe it belongs just where it is. It provides a superb interaction with industry and a much needed window on technology for the Department of Commerce. I would have great concern if one turned it also into a large contract funding agency. In short, something new is needed -- but what?

In my opinion, H.R. 481 has merit but is greatly flawed by incorporating the National Bureau of Standards, The Patent and Trademark Office and the National Technical Information Service. I do not see any desire or need for changing the mission of these groups. They seem to work well and are already where they belong. Rearranging money pots and people to make the effort look bigger and more coordinated rarely has a positive effect.

H.R. 1243 is, in my opinion, if taken alone, a way of postponing any positive action. It is my belief that H.R. 1243 can be accomplished within current legislation and administrative guidelines and should require only congressional encouragement without additional legislation. Such a study would be useful but not critical.

H.R. 2525 is aimed at the broad issue of a National Industrial Policy which has been recently debated with varying degrees of emotion and common sense. Let me start by saying that the issue is not whether or not we should have an Industrial Policy, for no policy or an infinate number of uncoordinated statutes and regulations dumped in a basket are already a form of an Industrial Policy. The issue is how coordinated or at least internally consistent should the policy be. I favor the purpose addressed by this bill since it only takes the first logical step of collecting the information about how conflicting and discouraging or how coordinated and supportive are the rules and regulations we now have taken all together. What we do with the results, in this instance, might best be left to decide until the results are in.

The purposes of H.R. 4361 as described in Section 6 and 7 are laudable objectives and are worthy of a more detailed examination as this bill is considered further. Rather than forming a new agency, however, it seems to me that many of its objectives already have some roots either currently or in history within the Department of Commerce. It is not clear to me why a new agency is required over a clear mandate to the Department of Commerce which now has a lean but knowledgeable staff in many of the areas of the bill. The 500 million dollars mentioned in the bill is, I'm sure, a roundhouse figure. Nonetheless, it is more realistic than the roughly 20 to 80 million mentioned in the other action oriented bills. Remember, to put these amounts in perspective, the Bureau of Standards gets 115 million and is considered to be only scratching the surface. Alternatively, the administration and salaries for the government bankruptcy courts is also about 100 million dollars.

Having said that, I must repeat the assertion that we are dealing with a fixed number of good minds. When we spend the equivalent of 500 million dollars worth of talent and support on this activity, we should ask what we are not going to have them work on. If we cannot find any activity of lesser importance to stop, we should re-examine how important this initiative really is.

Finally, I would like to comment briefly on H.R. 4407 and 4415. These bills are complementary approaches to a limited area of technology; namely, Automated Design, Manufacturing and Testing. However, in its present form, H.R. 4047 is restricted to Robotics and Automated Manufacturing Systems.

Although each of these bills has merit, they are both far too restricted in scope and in suggested funding. To proceed along those lines would inevitably lead to an automated office Bill, a bioengineering development Bill, a design for manufacturing Bill, and so on. It just seems to me that the issue we face is an issue of policy creation for the ongoing partnership between the private and public sector for the assurance of job creation, international competitiveness and the stimulation of the positive benefits of technology before the fact rather than government control of the negative effects of technology after the fact. If this is the case, then we should get on with the drafting of a comprehensive bill along the lines of H.R. 4361 rather than a piecemeal patchwork approach.

Mr. **Walgren**. Thank you very much, Dr. Pry. It is interesting testimony.

What are some of the political difficulties of mounting a major initiative in the area along the lines of H.R. 4361? I think in some sense it makes sense to identify the enemy, if that is the case. If there are attitudes or interests that are opposed, I suppose we have to really figure out who they are and see what direction is best to go in to try to get there.

Dr. **Pry**. With all respect, I think they are us. The difficulty that we have as a society in coming to grips with the appropriate role of the Government in the support of what is considered to be private enterprise in the end gives us a great pause. It is far better now than it was, say, 10 years ago in terms of the attitude at that time that the Federal Government should not spend any money which might result in a profit for a specific corporation. I think that view is beginning to turn around a little bit in recognition of the fact that that profit is trivial if the actual original work was done in the national interest. That profit is trivial compared to the job creation and national purpose that is served as a consequence of that incentive driven work that is done in the private sector as a result of Federal support.

Nonetheless, we still have a great deal of conservative thinking in this area, in my view.

The other problem, quite frankly, in this area of industrial engineering research is that it is not neat enough. It is not jazzy enough. We seem to have little problem in funding what I might consider cathedral building, that is, the space efforts and the high energy physics efforts that are to a certain extent, as I say, they are like building a cathedral in the Middle Ages. It is something beautiful to look at and delightful to behold, but may or may not have a dramatic effect on the well being of the citizens in the short run.

This, I think, has come out of an attitude that started in this country in the late 1940's and early 1950's and has persisted since that time. It is a relatively new attitude, if one looks back in history. It certainly was not the case around the turn of the century where we had a very great emphasis on technology. So, I think the problems are us. They manifest themselves by administration attitude, by some of us in the House and Senate taking positions that are adversary with respect to private enterprise and nonconstructive in that area, but I think that is simply reflective of an attitude of the country at large.

Mr. **Walgren**. What do you project in terms of future levels of unemployment when you look down the road? You emphasize, at the end of your statement, that what we really have is an issue of governmental policy to assure job creation. That is another area where we really have had a very uncertain trumpet from our political leadership, the view that the Federal Government really is not responsibile and should not feel responsible for the levels of employment or particularly job creation.

Dr. **Pry**. Well, we either have to have some responsibility for job creation or welfare, one of the two. Trying to draw a specific qualitative statement relative to what would happen if we did not start initiatives I think has to be related to what has been happening.

One might project, for example, the increasing deficit, in fact, on export/import in manufactured hard goods and take the general supposition that it takes on the order of, let's be generous, $200,000 of export sales per person employed, and just project those employment figures forward by industrial sector. You recognize what the national implications are of a continued trend in overseas purchases as opposed to both manufacturing for sale at home and international trade. And that is talking about it in terms of fixed current industries not including new areas.

Most of the new hires, of course, in industries and certainly most of the new hires in new fields are by small business starts, an area which I think has been largely neglected until very recently in Congress in looking at the question of job creation and stimulation. There has been a past attitude that you don't really have to spend money to help General Motors and to help General Electric where, indeed, in the manufacturing sector, roughly 2 percent of our companies account for something like half of the gross national product in that sector.

On the other hand, looked at another way, the other half is generated by people in companies of less than 500 people apiece. So, the small company's start and the small company's stimulation and growth is another area where I believe the Government in some of its newer initiatives is beginning to recognize that job creation is indeed part of its function.

Mr. **WALGREN**. I think you put your finger on something that is pretty important given the deficit and its impact on the trade balance.

Dr. **PRY**. I am sure you are more aware than I am that each of those people with a new job votes.

Mr. **WALGREN**. Well, that may be.

I would like to recognize the gentleman from Florida, Mr. MacKay, and I apologize because we are going to be interrupted here before we can finish with the witness, but I hope Mr. Boehlert can come back.

Mr. **MACKAY**. Dr. Pry, this is fascinating testimony. You, on page 3, put the spotlight on a very significant issue, and that is the shortage of trained, skilled, and innovative minds may be greater than the shortage of dollars as far as being a gate or a bottleneck in this whole technology and innovation stimulation process. You are saying if we pour more money into the other aspects of it and don't have more minds available, we many end up doing more things less well. I think that is a very interesting observation.

The question is, is government now doing some things that make that shortage worse? In other words, we are in our military R&D effort effectively funding a situation where they are more than competitive. It is more attractive to do research in the military area than it is in the civilian area.

Dr. **PRY**. You got the thrust of my remark very well. That indeed is it. If you look over past time, I have in a sense less concern over our expenditures in government R&D in military and defense sectors with respect to the money spent. I have less concern than I do with respect to the shifting in emphasis of not only the poeple who are mature and working in those fields but the training of young people. That is, we spend more and more money in these areas, we will continue to warp the direction of our national effort.

If one, for example, turned around and spent let's say $500 million in the industrial sector and didn't do it wisely, you may find, for example, if it were put into government laboratories, that all that you would do is steal more professors from the campus and make it less possible to generate the new people that we need. So, I think one has to be relatively careful in how one views this situation and to recognize that in the short run, you can have some adverse effects in what you think is a helpful policy by not thinking in advance what the real critical gate shortage is. That is really what I meant to say in those few statements.

Mr. MacKay. Your suggestion is that we should be equally cautious in tearing apart existing agencies and trying to solve problems by getting a tidy structure.

Dr. Pry. Yes.

Mr. MacKay. I agree with that, but the problem I have is I don't find any existing institution, either in the legislative or the executive branch, which is doing a good job of looking out to a longer term horizon and trying to identify where we might be going so that we could be dealing with the question of trying to be sure we have an adequate supply of manpower trained in the right directions and so forth. What agency should do that?

Dr. Pry. Well, the appropriate agency, as I mentioned in my remarks, I think the National Science Foundation is an excellent body in the area of education and research surrounding education which has to be a coordinated activity. I think they do that well. I am as frustrated as others with the fact that they are only spending 10 percent of their $1 billion budget on the area of engineering thrust, but that is being corrected. As you know, there is a new director there who has an industrial background. I think they are beginning to get the message. There is an internal cultural problem in trying to reassess where they are and where they are going, but I think that is a feasible thing.

On the other hand, when one starts to think about initiatives that are strongly coupled with industry, I think it is an inappropriate agency. They are structured for peer review among their equals. They are not used to setting priorities. They take things over the transom, and evaluate them, and I think that that is an inappropriate place for that kind of activity, but I would fully support NSF in its educational thrust, educational research thrust, and I believe that they are beginning to get on the path of emphasizing engineering research.

Mr. MacKay. Mr. Chairman, I would like to ask some more questions, but I think I have to be cowardly and go vote.

Mr. Walgren. It is true we ought to suspend and I know that Mr. Boehlert also has questions, so we will be back with the same witness. If you can join us, we will just take a 15 minute recess at this point. I am afraid it will be 15 minutes because this vote will then be followed by another 5 minute vote over there, so we will have to suspend for about 15 minutes.

[Recess taken.]

Mr. Walgren. Let us continue just for a second because I know Mr. MacKay had wanted to follow up and was stopped by the clock.

I wanted to ask, you are apparently given credit for saying something to the effect that technology transfer is a contact sport, and yet in your testimony, you are pretty pessimistic or you don't put much value in reorganizing these various departments. It would seem that at some point, oughtn't we to recognize the turf problems develop and the lack of contact from one agency to another and not being in the same structure really creates distance and an inability in a Federal bureaucracy, Governmental bureaucracy, of working together.

Dr. PRY. Yes; in a sense, you are right. On the other hand, my model for saying that reorganizing does not necessarily lead to advance is the case of the Department of Energy over some of its former agencies. What we did in particular in that case was to put regulation and stimulation in the same agency and I submit that that has some problems associated with it.

All I am really saying is that one has to think through what those new objectives are and why it is you are making that rearrangement, because if it simply is to group a set of seemingly like objectives into a pile without having some new thrust that you are really trying to do it for, it is a questionable practice. That is the reason for that remark.

Mr. WALGREN. I see.

Dr. PRY. I haven't been terribly impressed with a rapid increase in sideways communication within some of the large agency conglomerations.

Mr. WALGREN. Yes, but at the same time, you have to be impressed with the lack of sideways communication between governmental entities.

Dr. PRY. That is obviously true. I don't deny that. I think what my principal remark was that if one wishes to start a new kind of technology thrust for domestic industry that it properly belongs in the domestic industry agency, which is the Department of Commerce.

Mr. WALGREN. The gentleman from Florida. Did you want to follow up?

Mr. MACKAY. You may have covered the issue I was concerned about. It seemed to me that where you were headed, Dr. Pry, was to the conclusion that we need some kind of extension service component in the Department of Commerce.

Dr. PRY. That is correct. That is correct.

That part of that bill that is a somewhat broad character—I have forgotten what the number is—has an element in it which goes back to about the 1960's. When was that first proposed? As I recall it was somewhere around 1963 or 1964, the idea of an extension service in the Department of Commerce that was likened to the county agent system in the Department of Agriculture. That had a very, very brief existence in the debate process and was shot down in flames.

Yet, if you look at, for example, Georgia Tech, they have an extension service in the State of Georgia which seems to be working rather well, as a matter of fact, in having offices in towns around the country to try to do just that, to transfer technology to the smaller businesses in that State. It remains to be seen, I think, just how successful that is going to be in the long run, but in the short run, at least in my visits, it seemed to be working rather well.

Mr. **MacKay**. I guess the thing that got me thinking that was the comment that you don't need to help GM and you don't need to help General Electric; you need to help the small businessman. It turns out he is where most of the jobs are created and most of the innovation is taking place.

Dr. **Pry**. That is correct. At least my feeling, in looking at the productivity issue, and Japan has the same problem that we do in that case—we speak a lot about cold, dark factories like Fanuc in Japan, but if you look at the component factories, the factories producing components for those system factories, they are dark shacks at this point. So it is in this country, that if you look at the Boeings of the world or the General Electrics of the world that are putting in automated plants, that is fine, but you then have to ask where do they get the components to go into their products and what is the productivity of the incoming inventory, if you like, that comes from a wide variety of smaller industries in the United States. That may be the sticking point with respect to our productivity and productivity advantage over the Japanese in time.

So, we need to organize to help at that level, as opposed to thinking, as a Congress or administration or a people, that we are helping that 2 percent of the industries that supply half of the gross national product in manufacturing.

Mr. **MacKay**. Thank you.

Mr. **Walgren**. Thank you, Mr. MacKay.

Mr. Boehlert?

Mr. **Boehlert**. I have no questions, Mr. Chairman.

Mr. **Walgren**. Well, thank you very much, Dr. Pry. We appreciate your being a resource to the committee very much.

Dr. **Pry**. It is always good to talk to a fellow Pittsburgher.

Mr. **Walgren**. Thank you.

The next witness is Donald Vincent, executive vice president of the Robotics Industries Association.

Welcome to the committee. We are glad you are here. I apologize for the delays in the hearing this morning, but they are inevitable in some ways. Your written statement will be made part of the record as a matter of course. Feel free to proceed and outline as you like to communicate your points in whatever way you feel most effective.

STATEMENT OF DONALD VINCENT, EXECUTIVE VICE PRESIDENT, ROBOTIC INDUSTRIES ASSOCIATION

Mr. **Vincent**. Thank you, Mr. Chairman.

Mr. Chairman and members of the subcommittee, I am here today to represent the Robotic Industries Association. We are certainly grateful for this opportunity to present testimony on legislation, H.R. 4047, and H.R. 4415, which will foster, in our opinion, more automated manufacturing in the United States through the use and implementation of industrial robots.

RIA appreciates your invitation to address this hearing, and we realize that the need for improving the industrial robot market is something that needs to be brought to this testimony. Certainly, other methods of enhancing our Nation's productivity through automation are clearly stated in my formal testimony which we have submitted to the subcommittee.

For the sake of time and because of our small delay, I would like to paraphrase some of my testimony, but would proceed to say that it is ironic, Mr. Chairman, that the technology which originated in this country, the industrial robot—and we are now able to say industrial robot. Years ago we were using the words "universal transfer devices", but we have come a long way from UTD's to accepting the technology and the terminology "robot", in industry and in the public. It is ironic that the technology invented in America has been utilized more fully by our overseas trading partners who, taking full advantage of industrial robots, are using this technology to compete against U.S. manufacturers not only on the world market but more particularly here at home.

RIA was founded in 1974 as the U.S. Robotics Industry Trade Association and speaks for some 300 U.S. corporations made up of industrial and personal robot manufacturers, component and systems suppliers, and end users of the technology, and other groups from the research community now affiliated with our organization. RIA's membership has increased by 60 percent in the past year, which indicates that positive acceptance is taking place in the private sector for industrial robot technology. Yet, while our trade association continues to make progress, it is clearly understood that our industry is not moving ahead.

A recent report issued by the U.S. International Trade Commission illustrates the problems facing U.S. robot producers. Before I begin to detail some of the statistical information, I would like to point out that the numbers you are about to hear are far lower than the projections that our industry people make and industry analysts are making. We are currently undertaking a major project in a new industry like this to collect industrial statistics based on shipments, imports and exports, and have made some progress in getting a system started here recently that would give us actual industrial data on robot equipment that is manufactured and shipped both out of the country and brought into the country. For now, until we complete that project, we certainly are in a position to stand by the ITC work that is available and has received a lot of good credit from our industrial members of the trade association.

Currently, there are about 50 U.S. producers of industrial robots, and six firms account for 80 percent of the U.S. shipments. But beneath the limited number of producers that we have, there is a very important infrastructure of highly innovative, so-called high tech entrepreneurial firms supplying robot equipment and products ranging from small components to software systems. So, we are not just a trade association of robot suppliers but the components that go into producing these devices. This level of our industry is as vital to preserve as are the producers and users themselves.

In 1979, according to ITC, some $28 million in U.S. robots were sold, and the sales rose to $143 million in 1982 and to $169 million in 1983. However, the percentage of robot sales by U.S. producers to the domestic market dropped from 86 percent in 1982 to 80 percent in 1983. Imports are clearly on the rise as foreign robot producers move to capture a larger share of the U.S. market.

As the U.S. market grows, more jobs in the robotics industry are created. Employment in the U.S. robotics industry has increased, and if our industry continues to grow, we will have a large employment base throughout the United States in a few short years. We sincerely hope that these new jobs being created will remain in the United States and not leave our country.

Despite the growth in sales and projected employment, our U.S. robot industry's capacity remains grossly underutilized. Between 1979 and 1983, our plants ran at half capacity. In 1983, production dropped to 48 percent capacity and this situation became worse when new producers entered the industry in anticipation of a large demand for products, but that demand never materialized.

Our industry, as you well know, is research and development intensive. According to the ITC documents, our R&D expenditures in 1979 were $6 million. In 1983, our R&D accounted for $30 million. During that time, our industry suffered extensive losses. In 1982, the return was 42 percent of net sales and dropped even further to 49 percent of net sales in 1983. In short, Mr. Chairman, this industry needs help badly and promptly.

Meanwhile, our overseas competitors are off and running. Japan has installed, at the end of 1982, nearly 32,000 robots. By comparison, in the United States, we had installed just over 8,000. The Japanese increase from 1978 was due largely to government incentives, and in that time period, they installed some 22,000 robots. They now account for 64 percent of the robots installed worldwide. These are staggering figures and put some reality into the problem facing this industry and the use of our technology.

It is not too late to correct this situation. Certainly, Western Europe represents the best market for U.S. robots next to our own here at home. We continue to have a positive trade balance of robots, although it has steadily slipped from a high of $12.7 million in 1981 to $5.2 million in 1982 and dropped to $4.8 million in 1983.

The legislation pending before this subcommittee are positive steps toward improving the Federal Government's programs intended to assist the development of robotic technology. Certainly and clearly, the creation of centers for industrial technology would make a significant contribution to enhancement of data, exchanges of data, and increased public visibility for our industry. However, there must be ample protection for proprietary data in the role played by such a Federal center, as our industry is highly dynamic and protective of new development. In addition, as you now, robotic technology is becoming more and more vital to our national defense.

RIA also applauds expansion of the National Bureau of Standards' role through creation of Federal research centers on robotics and we submit that there be included in that agency some participation by our industry in NBS activities, particularly in the standards or guidelines setting area, because we have taken a lead role for the United States in creating guidelines that would develop into standards for both user and manufacturer.

RIA welcomes creation of the review board proposed in section 7 of the bill, H.R. 4047, with respect to the board consideration of U.S. tax laws applied to robots and automated manufacturing, leasing, and other policies affecting our industry. However, we would not want the creation of the board to in any way hinder efforts to bring about changes in the Internal Revenue Code to improve the industrial robot market here and abroad, or facilitate specialized leasing programs.

FIA favors the concepts embodies in the bill, H.R. 4415. To permit the Secretary of Commerce to enter into agreements with manufacturing industries not taking full advantage of automated technology is a positive step toward market improvement.

The identification and evaluation of technologically advanced manufacturing methods needed in declining industries as proposed in section 6 of H.R. 4415 has the support of our trade association, as certainly does the evaluation of retraining of workers. We expect that in the long term, employment will be improved by automation. If our national economy can be revived by improvements in manufacturing technology, employment will prosper.

Mr. Chairman, in addition to the support RIA offers for the legislation proposed here, a few additional suggestions are in order.

We strongly feel that in the coming months, the Congress should closely consider a special package to improve the U.S. industrial robot markets both here and abroad. After all, we feel you and your colleagues in the Congress would agree that not only is robotics good for U.S. manufacturing, but so is the preservation of our positive robotics trade surplus through export sales.

We propose the Congress consider the following six-point proposal to get America's basic manufacturing industry further down the road to recovery and competitive security:

The first point would be tax credits for use of innovative automated manufacturing technology.

The second would be low-interest loan guarantees to facilitate industrial robot leasing.

The third would be low-interest loan guarantees for direct purchase of industrial robots by undercompetitive U.S. industries.

Fourth would be export incentives through aggressive tax incentives for U.S. producers.

The fifth point is Small Business Administration low-interest loan guarantees to benefit small users and entrepreneurial robot suppliers unable to obtain such financing in venture capital markets.

Finally, sixth would be special educational incentives for applied robotics engineering and research.

The age of the industrial robot is coming. Whether the American industry survives with sufficient strength to compete in our own market as well as those abroad is in large a decision to be made in this Congress.

One day soon, the market problems will be solved by increased demand. We are very optimistic about this. I am sure you would agree that that market should be served not just by a technology invented here but by a second, third, and even fourth generation of robots developed in America as well.

Thank you, and that concludes my semiformal testimony.

[The prepared statement of Mr. Vincent follows:]

ROBOTIC INDUSTRIES ASSOCIATION

STATEMENT BEFORE

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, D.C.

June 14, 1984

Mr. Chairman and Members of the Subcommittee:

The Robotic Industries Association (RIA) is grateful for the opportunity to present testimony on legislation (H.R. 4047, 4415) to foster more automated manufacturing in the United States through the use and implementation of industrial robots.

RIA also appreciates your invitation to address the need for improving the industrial robot market in the U.S., and other methods of facilitating our nation's productivity through automation.

It is ironic, Mr. Chairman, that a technology which originated in this country - the industrial robot - and which offers such promise to our domestic heavy manufacturing industries, is having such a diffcult time moving forward. It is even more ironic that this technology invented in America has been utilized more fully by our overseas trading partners who, taking full advantage of industrial robots, are using our technology to compete against U.S. manufacturers not only on the world market but more particularly here at home.

RIA speaks for some 300 U.S. corporations made up of industrial and personal robot manufacturers, components and systems suppliers, end users, and other groups involved in robotics. Founded in 1974 as a trade association managed by the Society of Manufacturing Engineers, RIA became independent in 1983, and has seen a 60 percent increase in membership since then.

Yet, while our trade association is clearly on the move, our industry is not.

A recent report issued by the United States International Trade Commission (ITC) illustrates the problems facing U.S. robot producers. Before I begin detailing the statistical information, I should point out that the numbers you are about to hear are far lower than the projections made by the industry analysts.

Our trade association is currently compiling accurate authoritative statistics that will reveal the true state of our industry. Until the project is completed, we stand by the ITC statistics as the best that are currently available.

Though there are currently about 50 U.S. robot producers, six firms account for about 80 percent of U.S. shipments. But beneath the limited number of producers lies a very important infrastructure of highly innovative so-called "high tech" entrepreneurial firms supplying products ranging from small components to software systems. This level of our industry is as vital to preserve as are the producers and end users themselves.

In 1979, according to ITC, some $28 million in U.S. robots were sold, and the sales rose to $143 million in 1982 and to $169 million in 1983. However, the percentage of robot sales by U.S. producers to the domestic market dropped from 86 percent in 1982 to 80 percent in 1983. Imports are clearly on the rise as foreign robot producers move to capture a larger share of the U.S. market.

As the U.S. market grows, more jobs in the robotics industry are created. Employment in the U.S. robotic industry has increased dramatically and if our U.S. industry grows we will have a large employment base throughout the U.S. in a few short years. We sincerely hope that the new jobs being created by the industry will remain in the United States.

Despite the growth in sales and projected employment, our U.S. robot industry's capacity remains grossly underutilized. Between 1979 and 1983 our plants ran at half capacity. In 1983, production dropped to 48 percent capacity and this situation became worse when new producers entered the industry in anticipation of a demand which has not yet materialized.

Our industry, as you well know, is research and development intensive. According to the ITC, R & D expenditures in 1979 were $6 million. In 1983, R & D accounted for $30 million. During that same period the industry suffered extensive losses. In 1979, the median return was 23 percent of net sales. In 1981, the return declined to a loss of nine percent of net sales. In 1982, the decline reached 42 percent and dropped again to 49 percent of net sales in 1983. In short, Mr. Chairman, this industry needs help badly -- and promptly!

Meanwhile, our overseas competitors are off and running.

Japan had installed, as of the end of 1982, 31,900 robots. By comparison the U.S. had installed 8,000 robots. The Japanese had an increase of 22,000 robots installed since 1978 due largely to government incentives. Japan now accounts for 64 percent of the robots installed worldwide. Japanese users have four times more robots than do their U.S. counterparts. "In fact, there are more robots installed in Japan than in all other countries combined." says the U.S. International Trade Commission.

It is not too late to correct the situation. Western Europe represents the best market for U.S. robots next to our own. We continue to have a positive trade balance of robots, although it has steadily slipped from a high of

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$12.7 million in 1981, to $5.2 million in 1982, and dropped to $4.8 million in 1983.

Mr. Chairman, the legislation pending before this Subcommittee are positive steps toward improving the organization of the federal government's programs intended to assist the development of robotic technology. Clearly, the creation of Centers for Industrial Technology would make a significant contribution to enhancement of data, exchanges of data, and heightened public visibility for our industry. However, there must be ample protection for proprietary data in the role played by any such federal center, as our industry is highly dynamic and protective of new development. In addition, as you know, robotic technology is becoming more and more vital to our national defense.

RIA also applauds expansion of the National Bureau of Standards' (NBS) role through creation of a Federal Research Center on Robotics, and we submit that there be included in that agency some participation by our industry in NBS activities, particularly as standards, or guidelines-setting, is an area very much underway within RIA.

RIA welcomes creation of the Review Board proposed in Section 7 of H.R. 4047, particularly with respect to Board consideration of U.S. tax laws applicable to robots and automated manufacturing, leasing and other federal policies affecting our industry. However, we would not want the creation of the Board to in any way hinder efforts to bring about changes in the Internal Revenue Code to improve the industrial robot market here and abroad, or facilitate specialized leasing programs.

RIA favors the concepts embodied in H.R. 4415. To permit the Secretary of Commerce to enter into agreements with manufacturing industries not taking full advantage of automated technology is a positive step toward market improvement.

The identification and evaluation of technologically advanced manufacturing methods needed in declining industries as proposed in Section 6 of H.R. 4415 has the support of RIA, as certainly does the evaluation of retraining of workers displaced by declining industries. We expect that in the long-term employment will be improved by automation as workers currently suffering from unemployment in American firms made no longer competitive by automation overseas find new jobs in a national economy revived by improvements in manufacturing technology.

Mr. Chairman, in addition to the support RIA offers for the legislation proposed here, a few additional suggestions may be in order.

We strongly feel that in the coming months the Congress should closely consider a special package to improve the U.S. industrial robot market both here and abroad. After all, we feel you and your colleagues in the Congress would agree that not only is robotics good for U.S. manufacturing, but so is the preservation of our positive robotics trade surplus through export sales.

We propose the Congress consider the following six point proposal, though stated in general terms, to get America's basic manufacturing generally, and our industry specifically, further down the road to recovery and competitive security:

1. tax credits for use of innovative automated manufacturing technology;

2. tax credits, including the ability to "sell" unused credits (as in the 1981 Economic Recovery Tax Act's "safe harbor" leasing provisions), and low interest loan guarantees to facilitate industrial robot leasing to depressed industries;

3. low interest loan guarantees for direct purchase of industrial robots by undercompetitive U.S. industries.

4. export incentives through aggressive tax incentives for U.S. producers or expanded Export-Import Bank loans;

5. Small Business Administration low interest loan guarantees to benefit small users and entrepreneurial robot suppliers unable to obtain financing in venture capital markets;

6. special educational incentives for applied robotics engineering.

Mr. Chairman, the age of the industrial robot is coming. Whether the American industry survives with sufficient strength to compete in our own market as well as those abroad is in large part a decision to be made in the Congress.

One day soon, the market problems will be solved by increased demand. I am sure you would agree that market should be served not just by a technology invented here but by a second, third, or fourth generation of robots developed in America as well.

Thank you.

ROBOTIC INDUSTRIES ASSOCIATION
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DONALD A VINCENT, CAE

Donald A. Vincent, CAE, has been executive vice president of the Robotic Industries Association (formerly Robot Institute of America) since June 1, 1983.

Vincent joined RIA in February, 1983 as assistant to the executive director after nearly 14 years with the Society of Manufacturing Engineers. While at SME, Vincent led the Society's Computer and Automated Systems Association and the North American Manufacturing Research Institute. He also held various staff positions in member and chapter relations, technical activities, government relations and association management.

Vincent is a Certified Association Executive (CAE) and a member of the American Society of Association Executives, the Association Executives of Metropolitan Detroit and the Council of Engineering and Scientific Society Executives. He received his Bachelor of Science degree in marketing from Ferris State College, Big Rapids, MI, in 1969. Vincent and his family reside in Westland, MI.

The Robotic Industries Association (RIA), headquartered in Dearborn, MI, was founded in 1974 and is the only robot trade association serving North America. RIA sponsors the largest robot equipment exposition in the world and conducts industry-related programs for over 300 robot manufacturing, user and research companies.

Mr. **Walgren.** Thank you very much, Mr. Vincent. We appreciate that.

The Chair would like to recognize, in view of the time constraints, Mr. Boehlert.

Mr. **Boehlert.** Thank you, Mr. Chairman.

Thank you, Mr. Vincent. I really apologize, as the chairman already has, for the crazy, mixed-up schedule that has had you so long delayed. I would welcome the opportunity to be here with you longer for questioning because I think you have a very thoughtful statement, and you touch on a number of points that are of deep personal interest to me. But schedules are such that I have to depart shortly, and I thank you, Mr. Chairman, for this courtesy.

You said, at the tail end of your statement, that the age of industrial robots is coming. I submit to you it is already here. That is music to your ears, isn't it?

Mr. **Vincent.** It certainly is and we should begin to see improved sales.

Mr. **Boehlert.** There is no question about it that we are in the race, and we would like to win it. I think it is very apparent that this committee is devoting a good deal of time and attention to the subject, and that is why you see generated bills like the ones you are testifying in support of.

Part of the problem, obviously, is a perception problem, and although we are over that problem about what we call it, we now call it robots, I think there is a great concern that if we don't do anything we are going to save jobs. That just isn't so. If we don't do anything, we are not going to be competitive, and the Japanese are going to continue to do what they are doing very effectively right now, advancing in this area of technology making their industry more competitive. So, in the long run, we are going to lose jobs.

However, my concern is, and we had a chance just yesterday to talk about this, is the human equation. What about all those people who are going to be displaced by robots? First of all, do you have any figures on them? You indicated we have 8,000 robots in this country. Do you know how many jobs were displaced by those robots?

Mr. **Vincent.** Not in my mind at this time to give you exact figures, but I do know that there are a number of studies that have been done with figures in them. Some we would agree with; some we wouldn't, but I would like the record to be kept open so I could give you a document called "Robots Make Work." In there it describes some of the numbers you are looking for plus the areas where we expect this technology to move away from the metal working industry. It is predominantly a automotive industry used technology right now and in heavy manufacturing and metal working. After that, the next step would be to go into the textile industry, the food industry, and health care industries. Again, we believe tracking, much like the computer industry did. When that technology was first introduced, certainly the computer displaced people, but look at the number of jobs that were created because of the computer technology that we have today.

However, I will be happy to submit figures.

[Material to be supplied follows:]

Robots Make Work

The Greek philosopher Aristotle wrote, "if every instrument could accomplish its own work, obeying or anticipating the will of others...if the shuttle would weave and the plectrum touch the lyre without a hand to guide them, chief workmen would not want servants, nor masters slaves." Twenty-four centuries later, THE ROBOTS ARE COMING or similar headlines appear above numerous articles and editorials about industrial robots. Unlike Aristotle's vision of potential benefit to mankind, these pieces usually go on to predict massive losses of jobs by the end of the decade. Depending upon the source of data, these predictions range from one to three million jobs lost to robots by the end of the 1980's and possibly as many as seven million by the year 2000. Projections of job creation are of similar magnitude, ranging from 800,000 to 1.5 million new opportunities for robotics technicians and engineers by 1990, but still far short of balancing the predicted job losses.

For a technology now in only its third decade and continuing to show only modest growth, robotics seems to generate an inordinate amount of misinformation and emotion; misinformation about what robots can do and how fast their population is growing and emotion about their impact upon the workforce and society. A study in 1982 by the Congressional Budget Office projected that robots installed in manufacturing operations could require billions of dollars annually in federal aid to displaced workers, by the end of the 1980's. On the other hand, futurists Marvin Cetron and Thomas O'Toole estimate that there will be as many as 1.5 million robotics technicians on the job by 1990.

Just where do robots stand on the industrial scene in the U.S. and overseas and what is to be the likely scenario for the rest of the decade and beyond?

The first industrial robot was installed in a U.S. manufacturing plant in 1961. Despite a great deal of interest, acceptance of robots proceeded at a slow pace during the 1960's and early 1970's. In their first decade, only about 600 robots were produced. From the mid-70's on, however, installations increased steadily and the technology also spread throughout the industrialized world. At year-end 1982, there were more than 6,500 robots in use in North America, about 32,000 in Asia and almost 9,500 in Western Europe.

Robot technology has also grown, undergoing a steady transformation from electro-mechanical switches to microprocessor controls and from large, cumbersome hydraulic arms to a wide array of configurations, sizes and drive systems. Applications have evolved from simple pick-and-place tasks to complex tool handling operations such as arc welding and painting. Force, tactile and image processing sensors have given some robots rudimentary senses of touch and sight. Computers, vision systems and microwave communications provide robots limited mobility and with electronic voice synthesis, robots can even talk.

Despite all of these technological advances, the majority of today's industrial robots are applied to methodical, routine tasks. Few presently are fitted with advanced sensors and most are, thus, only capable of performing blind, repetitious operations. However, they provide their owners with nonvarying performance, are highly reliable, can handle heavy loads and can operate in hostile environments. They can replace workers on dangerous, fatiguing and demeaning jobs. Small wonder that robots are almost universally well accepted in the workplace.

At this time, the positive attitude of displaced workers toward robots can be attributed to two factors: the robot-like jobs from which the workers are removed and the common practice of providing these workers with other jobs. In some companies, at least 26 weeks of employment at the same or higher pay are guaranteed by contract to the displaced workers; retraining benefits are also often provided. Even when not contractually obligated, most companies retain displaced workers and depend upon normal attrition to balance out the workforce. Thus, robots are not seen as a direct threat to one's means of livlihood and may be perceived as improving the quality of one's work life.

Will this situation change as more and more robots are introduced into the workplace? If several million workers are displaced, as some predict, will most companies be able to continue to employ them or will significant layoffs result? And what of the robotics industry itself; how many new jobs will be created in this field? An optimistic view is expressed by robotics expert Dr. James Albus (The Futurist, February 1983) who states that, "Robot production will add jobs to the economy about as fast as robot installation takes them away," and that "entirely new robot manufacturing, sales, and service industries will emerge and millions of exciting new jobs will be created."

The most likely scenario is described in Allen and Timothy Hunt's book Human Resource Implications of Robotics, published in 1983 by the W.E. Upjohn Institute for Employment Research. According to the Hunts, the total U.S. robot population in 1990 will range from 50,000 to 100,000 units. Based on this estimate, they project the elimination of between 100,000 and 200,000 jobs in manufacturing, with about one-fourth of those being in the automobile industry. The Hunts also foresee the robot industry creating from 32,000 to 64,000 new jobs in the U.S. by 1990, in robot manufacturing, supplying goods and services to robot makers, robot systems engineering and in user applications. It is unlikely that many of those displaced by robots will find work in the robot industry however, because semi-skilled or unskilled jobs are eliminated, while the jobs created will require significant technical background.

Regardless of the numbers, robots will make work. Robotics technicians (most likely with two years of technical training or equivalent hands-on experience) will test, program, install, troubleshoot or maintain robots and will be employed by robot makers and robot users. Robotics engineers (mostly mechanical and electrical engineers) will design the products for the robot manufacturers. Applications engineers (mostly manufacturing and industrial engineers) will identify and develop robot applications for users and will design systems, prepare proposals and support sales for robot makers and systems integrators. Other scientists and engineers will develop computer controls and sensors (vision, touch, force) for the "intelligent robots" of the future. The robot industry will require an infrastructure of educators, component suppliers, and system integrators, as well as computer programmers, managers, sales and marketing specialists, and administrative and clerical personnel.

Looking beyond 1990, non-manufacturing applications of robots will become practical. Robots will be found in the construction industry; in mines; on farms; under the sea;and in space. Robots will be found in service occupations in hospitals and long-term health care facilities; in retailing; in food preparation; as security guards, fire fighters and disaster workers; even in the military services. In many cases, these robots will not displace humans but will perform their back-breaking, boring or dangerous tasks under human direction.

The area of robotics which may have the greatest impact in the future is the personal or household robot. Already, more than two dozen companies are developing or building such robot products. Today's personal robot has limited capabilities and is noted more for its novelty and entertainment value than for its functionality. However, some of these mobile robots incorporate ultrasonic or infrared sensors, voice synthesizers, fiber optics vision systems, and wireless data communications, features which are not common on most industrial robots. Many are designed to be interfaced with personal computers and, like the personal computer, the personal robot may someday create thousands and thousands of new jobs without putting anyone out of work.

Today's industrial robots are few in number and limited in ability; robotics activities in the U.S. probably employ more people in 1984 than the robots have displaced. By the end of the decade, however, measurable job displacement will take place in manufacturing industries. Increased demand for robots, new robot applications in non-manufacturing areas, new robot products, and new technology all will combine to create new opportunities, but will require new skills. Also, by 1990 the number of people entering the workforce each year will be smaller and they will be better educated. Thus, the long-term outlook for robotics is positive; as James Albus says, "The new age of robotics will open many new possibilities. What we humans can do in the future is limited only by our imagination to see the opportunities and by our courage to act on our beliefs."

Mr. **Boehlert**. Also, if you don't have the figures readily available, could you submit for the record the number of jobs that are directly related to the production of robots?

Mr. **Vincent**. Yes, sir.

Mr. **Boehlert**. R&D and all.

Mr. **Vincent**. The type of jobs directly related to this industry that will be created because of more robots being in the field. We will need more people to actually build robots and service and maintain them. Skilled trades people certainly will have a role in this industry as it progresses and makes more impact on all industry.

[Material to be supplied follows:]

EMPLOYMENT IN THE U.S. ROBOTICS INDUSTRY

In 1983, total employment in the U.S. robotics industry by reporting firms is estimated at 2,251 employees, which includes 969 production and related workers and 1,282 employees involved in engineering, sales, administration, and general office work (table 5). In 1979, there were 716 persons employed by these firms, including 376 production and related workers, supported by a combined total of 340 engineers, salesmen, and administrators. Employment increased by an average of 384 workers per year during 1979-83, or at an average annual rate of about 34 percent. Employment in the U.S. robotics industry, however, remains at a relatively low level (by comparison, it amounts to less than 5 percent of employment in the U.S. machine tool industry).

Employment of production and related workers more than doubled during 1979-81 but remained flat during 1982, when the growth in total shipments of U.S.-produced robots slowed to an annual rate of 26 percent, down from a 77 percent annual rate in 1981. In contrast, employment of professional workers increased in 1982 and overall experienced more rapid growth during 1979-82. The rapid expansion of producers' R&D projects accounted for a large share of the increase. In addition, R&D projects helped to stabilize the growth in employment of professional workers, since expenditures on R&D continued to increase in 1982 while employment of production workers remained largely unchanged.

As shown in table 6, employment of both production and professional workers should experience moderate growth during 1983. According to producers' estimates, average employment of production workers in 1983 is projected to be about 18 percent higher than that in 1982. Average employment of professional workers is expected to be about 16 percent higher. The growth in employment is not expected to exceed the growth in total shipments (in dollars) of U.S. produced robots, largely because certain producers contributing to the increase in employment are expected to purchase more robot assemblies in lieu of in-house fabrication.

Average employment in reporting establishments during 1979-83 became more dependent on production of robots relative to the production of other products. Most new producers entering the market deal exclusively in robots. In addition, employment in other product lines (e.g., machine tools) of established producers has declined substantially in recent years. As a result, all persons involved in the production of robots as a share of all persons involved in the production of all products in reporting establishments has increased significantly, from about 7 percent of all employees in 1979 to about 21 percent of all employees in 1982. In 1983, all workers involved in the production of robots are expected to account for nearly 25 percent of all workers in reporting firms.

Source: COMPETITIVE POSITION OF U.S. PRODUCERS OF ROBOTICS
IN DOMESTIC AND WORLD MARKETS p. 19-21
International Trade Commission
Washington, DC

Table 5.--Robots: Capital investments of U.S. producers, 1979-83

(In thousands of dollars)

Year	Land or land improvements	Building or leasehold improvements	Machinery, equipment, and fixtures	Total
1979	155	1,449	1,916	3,520
1980	-	1,766	4,486	6,252
1981	-	3,504	6,934	10,438
1982	450	4,512	7,390	12,352
1983 1/	10	1,520	5,716	7,246

1/ Data are based on projections provided by U.S. producers.

Source: Compiled from data submitted in response to questionnaires of the U.S. International Trade Commission.

Table 6.--Average number of employees in U.S. establishments producing robots, 1979-83

Item	1979	1980	1981	1982	1983 1/
Average number employed in the reporting establishments producing all products:					
All persons 2/	9,667	8,974	10,380	9,413	9,021
Production and related related workers 2/	5,452	4,968	5,473	4,307	4,510
Average number employed in the reporting establishments producing robots:					
All persons	716	1,032	1,672	1,934	2,251
Production and related workers	376	507	816	820	969

1/ Data are based on projections provided by U.S. producers.

2/ Employment data on all products were not included for 1 firm to prevent disclosure.

Source: Compiled from data submitted in response to questionnaires of the U.S. International Trade Commission.

Mr. **Boehlert**. Finally, just let me say that, if I can offer a little public relations counsel in your work, and I am very supportive of it, but consider always the human equation. So, I would appreciate it if your association would take a very hard, serious, thoughtful, deliberative look at the individual training account legislation with which I am identified. We now have some 60 cosponsors in the House, on both sides of the aisle. If we can proceed with development of robots which is clearly in our national interest, but at the same time be able to tell the American people that those workers who will ultimately be displaced by robots will have some source to go to get the training they need in new skill areas where there is a job waiting at the end of the training period, that is extremely important.

One of the reasons you are having so much problem getting a lot of excitement generated in organized labor, for example, about the work with robots is because they see a loss of jobs for their membership. If we can offer something that says yes, we are going to proceed with the development of robots, it is clearly in our national interest, it is going to make us more competitive, but we are also vitally concerned with those people that will be displaced and we are in support of a program that will provide these displaced workers with the training they need to get back into the job market.

So, I would hope you would take a good hard look at that. I know you have been exposed to it ever so briefly.

Mr. **Vincent**. I would certainly support your comments. On a personal level, one thing I see in the job that I have as the trade association director is that people need to be given some incentive to go out and find that training. It is awfully expensive for the hourly worker to be able to afford training at universities and colleges now. I think there needs to be—I have laid out the incentives that I think our industry needs—I think there is another testimony that should be given on incentives people need to find education and be able to afford it and pursue that education with the hope that when they are finished, there will be a job there waiting for them.

Some universities and technical colleges have changed curriculum titles to include more identity with robotics. They had a crush in the registrar's office to get into those programs and they had to close the doors in some cases, yet with all these people being trained and given certificates of accomplishment, there are no robot-related jobs. More people are employed in the robot industry now than there are robots in the field. The educational process is creating a lot of people that are looking for jobs, and they are just not there right now, until sales in our industry move ahead. So, I support what you have said about training.

Mr. **Boehlert**. Thank you.

The other thought I have is that obviously we have to do a better job in terms of the Government providing R&D money for our university research centers, particularly zeroing in on this subject. I know about the glamour ones, Brigham Young, Carnegie-Mellon, and Purdue, but there are others not so prominent but hopefully, they will be prominent in the future. I have one in my own congressional district, the College of Technology for the State University of New York. We are trying to encourage the development of a comprehensive program there, but it is very expensive. So, I would hope that you would be very supportive of Federal funding for that type of R&D at our university centers.

Mr. **Vincent**. Certainly. For direction alone, I guess it would be good to say that we need more applied robotics research. This industry will move ahead when some of the scientific research moves from the laboratory onto the production floor. Our counterparts in other countries throughout the world seem to be much better than us in applying the technology.

Our association is not willing to admit that we are lagging in the development of the technology, but certainly in the application of the technology. We would support any Government program that would create more R&D applied research capability for our people.

Mr. **Boehlert**. I apologize for having to leave, and I thank you for your testimony I will be in touch.

Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Boehlert.

Mr. MacKay?

Mr. **MacKay**. If I could just ask, would you elaborate on the Government incentives in Japan that you mentioned in your testimony that has resulted in their rapid expansion of robots? Are there particular ones with respect to robots that they are targeted on?

Mr. **Vincent**. We found, in our communications with the Japan Industrial Robot Association, which is a counterpart to our organization here, that they worked very closely with Ministry of Industry and Trade, called MITI, I believe, which creates programs that users need for applying the technology and they are directly related to robots. Japan certainly has surpassed the rest of the world in applying the technology. The Government programs such as starting a Government leasing robot activity, where companies and organizations can lease robots from the Government at low-cost rates to bring in and apply robots to specific production situations.

Again, I am not suggesting the U.S. Government become a leasing company. I think there is plenty of private sector leasing organizations that could handle such a leasing venture, but the Japanese idea seems to have created the most attention in our industry from both manufacturer and users.

Mr. **Walgren**. In Japan, the Government leases the robots?

Mr. **Vincent**. In Japan, it is called JAROL, the Japan Robot Leasing Co., started through the Government. I could send information to the committee on that, too.

Mr. **Walgren**. I see. That would be interesting if you have anything that is not too long.

[Material to be supplied follows:]

JAPAN ROBOT LEASE (JAROL)

With MITI encouragement, if not direction, a robot leasing company, Japan Robot Lease, (JAROL), was founded in April, 1980 with the initial paid-in capital of ¥100 million. This company is jointly owned -- 70% by 24 JIRA members and 30% by ten casualty insurance companies. The aim of JAROL is to support robot installation by small and medium-scale manufacturers and increase their productivity. As 60% of operating funds are financed by low-cost loans from the government's Japan Development Bank, and the rest from the Long-Term Credit Bank, Industrial Bank of Japan and the city banks, JAROL is in a position to lease industrial robots under conditions more advantageous than the ordinary leasing companies. For its first year of operation (fiscal year 1980), JAROL planned ¥700 million robot leases; actually its leasing contracts numbering 52 amounted to ¥1,150 million (about $5.7½ million). The average term of the lease was 6.5 years and provided a full payout. In April, 1981 JAROL offered a more flexible 2-3 year rental agreement (not a full payout) and after the expiration of the agreement planned to rent the robot to the same or a different user. At the same time JAROL began discussions with MITI to enter overseas leasing of robots. This resulted from a request of an Australian firm to lease Japanese-made robots. Some questions arose as to the propriety of using government loans for overseas leasing but JAROL suggested loans from the Japan Export and Import Bank. Positive action on this matter will greatly strengthen Japan's competitiveness in overseas industrial robot markets.

MITI has arranged for direct government low-interest loans to small and medium-scale manufacturers to encourage robot installation for automating processes dangerous to human labor and for increasing productivity. The government budgeted for fiscal year 1980 ¥5.8 billion for these loans which are extended through the Small Business Finance Corporation, a government finance agency.

MITI has permitted the manufacturer who installs a robot to depreciate 13% of its initial purchase price in the first year in addition to taking ordinary depreciation. This extra depreciation is a common practice in Japan when MITI seeks to promote a particular industry or product. Extra depreciation has been as high as 50%. Generally it can be taken over a three-year period and is usually repaid in five annual installments beginning in the sixth year. By installing an industrial robot, a firm can depreciate 53% in the first year, 13% plus 40% (5 year depreciation double declining).

MITI created an atmosphere favorable to the introduction of the industrial robot, but it had depended largely on the private companies to determime the direction and scale of production and to undertake R&D. The number of robot research laboratories in universities and public research institutions grew from 43 in 1974 to 85 in 1980. Some 270 researchers at colleges and universities and 80 researchers at institutes worked on robots in 1979.

In 1981, MITI announced a seven year ¥30 billion national robot research program beginning April 1, 1982 to develop Japanese robot technology instead of relying on imported know-how. Stress is to be placed on intelligent robots especially for assembly work, and on robots for nuclear, space, oceanic, and earth-moving industries. The development of sensory perception, language systems, and motional capacity are to receive top priority.

Source: ROBOTICS IN JAPAN: PAST, PRESENT, FUTURE p. 13-14
Paul H. Aron, Executive Vice President
Daiwa Securities America Inc.
New York University

Mr. WALGREN. Do we sell to Japan? We sell robots to Europe. Do we export much in this area to Japan?

Mr. VINCENT. Not much. There are a few companies that export to Japan, but the only way they have been able to do business is to actually go over there and find a distribution company or some joint manufacturing activity in Japan where parts of the robots are made over here and assembled and sold in Japan. It is a very small part of the export business.

The original agreement between Kawasaki and one of the leading robot companies, Unimation/Westinghouse, was conceived back in the 1960's where Kawasaki began to build very similar and almost the same robot that was created here. That became a major robot product in Japan with technology that was, again, invented here, taken over there, and licensed to build in Japan.

Mr. WALGREN. You mentioned the Bureau of Standards role in the creating of a Federal research center in robotics. Has your industry had any difficulties in relating to their activities out there? Do you feel that they have been exclusive at all?

Mr. VINCENT. Our relations with NBS has been developed over 10 years' existence in this community, and we have worked jointly in producing robot research workshops for industry suppliers and users. We certainly look at NBS as one of the key locations, Judging from the subjects that they encompass in their work out there, I think they are on the leading edge of what needs to be done to create centers of this type. It would be a good focal point to direct some Government initiatives and funding.

Mr. WALGREN. To what do you attribute the great decline in sales in 1982 and 1983 and the increase in losses of the companies in the robotics area?

Mr. VINCENT. Primarily the economic climate during that time period, but in addition to that, pricing. There has been an influx of foreign equipment brought into this country and distributed through incorporated organizations in the United States and pricing has gotten to be very competitive. There is a tremendous amount of supply right now of robot equipment, but it appears that the majors and some of the new startup companies are all looking for the one or two big orders that are out there. The orders just haven't come in.

Users have accepted the technology. We had our national trade show just last week, and we had an outstanding attendance of 23,000 people and 250 exhibitors in the show, more than ever, larger spaces than ever, yet the sales have not developed. There is an overabundance of suppliers in the industry right now. You will see some consolidation, I think, in the future in this industry, and we will end up with some key robot suppliers in certain application areas. The day of the robot being built to do everything, I think, will change and we will have more robots specifically being built for product lines or application areas, such as paint spraying, loading and unloading of machines, material handling, and even small parts assembly. The next major breakthrough should come in robots being used for assembly processes.

Mr. WALGREN. I see. All right. We certainly appreciate your testimony and the contribution you have made to the record. We look forward to discussing with the other members the points that you have developed.

Mr. **Vincent**. Thank you very much.

Mr. **Walgren**. Thank you.

This concludes several days of hearings in this area. The subcommittee will be talking among itself to see what areas of consensus we can develop in hopes of developing some concrete legislation that we could project the proper amount of support for. We appreciate you in the audience and your interest in the area and want to encourage you to contact the staff and the like if there is any information or any other viewpoints that you think we should be trying to take into consideration. We should be available to you on that level.

Thank you very much, Mr. Vincent.

This will conclude our hearing.

[Whereupon, at 12:25 p.m., the subcommittee recessed, to reconvene subject to the call of the Chair.]

APPENDIX

ADDITIONAL MATERIAL SUBMITTED FOR THE RECORD

TEXAS ENGINEERING EXPERIMENT STATION
Office of the Director

June 22, 1984

The Honorable Doug Walgren
House Subcommittee on Science, Research and Technology
2319 Rayburn House Office Building
Washington, D.C. 20515

Dear Congressman Walgren:

The enclosure contains my comments offered in support of H.R. 4415, companion legislation to S.1286, Manufacturing Sciences and Technology Research and Development Act of 1983.

Thank you for this opportunity.

Sincerely,

Newton C Ellis

Newton C. Ellis
Assistant Director

NCE:ssr

cc: Mr. Michael A. Lytle
Special Assistant to the Chancellor
Federal Relations

The Texas A&M University System • Engineering Research Center
College Station, Texas 77843-3577 • (409) 845-1321

SUBMISSION FOR THE RECORD

BY

DR. NEWTON C. ELLIS, P.E.

PROFESSOR AND HEAD

DEPARTMENT OF INDUSTRIAL ENGINEERING

AND

ASSISTANT DIRECTOR FOR RESEARCH

TEXAS ENGINEERING EXPERIMENT STATION

TEXAS A&M UNIVERSITY

TO THE HEARING ON

H.R. 4415

MANUFACTURING SCIENCES AND TECHNOLOGY

RESEARCH AND DEVELOPMENT ACT OF 1983

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

UNITED STATES HOUSE OF REPRESENTATIVES

JUNE 13, 1984

Mr. Chairman and members of the Subcommitte on Science, Research and Technology, I am Dr. Newton C. Ellis, and I am affiliated with Texas A&M University where I serve as Professor and Head of the Department of Industrial Engineering and as an Assistant Director for Research in the Texas Engineering Experiment Station. I have been with Texas A&M University in various capacities since 1969, and during the ten or so years prior to that, I was primarily employed in various aerospace manufacturing divisions of LTV, Inc., in Dallas, Texas. I am pleased to have the opportunity today to add my support to Bill H.R. 4415, cited as the "Manufacturing Sciences and Technology Research and Development Act of 1983."

If it pleases the committee, my intentions are to confine my brief remarks to two aspects of H.R. 4415: (1) My impressions regarding the "Findings" of Congress upon which the Bill is based, and (2) my recommendations for implementing the "Purpose" of the bill. Given these two aspects, may I now turn your attention first to my impressions regarding the congressional "Findings" which served as the impetus for H.R. 4415. Although the "Findings" are only nine in number, I will forego repeating them because repeating them to this audience would serve no useful purpose. However, I should stress that in my judgment these "Findings" are valid; they clearly describe the situation in American manufacturing today, and the picture they paint is not good.

Despite a bright spot here and there, the situation in American manufacturing industries, for the most part, has continued to deteriorate since the mid 1960's, and this is puzzling to say the least. Although we recognize that manufacturing industries are essential to the economic well-being of our nation, sufficient attention, nevertheless, has not been given to keeping these industries healthy. I will mention only a few examples for illustrative purposes - research expenditures have not kept up with needs for modernization and changes in the state-of-the-art; large portions of our manufacturing equipment, methods and processes are worn out and obsolete, and as a result, foreign competition outproduces several of our important industries. We find ourselves today experiencing conditions that threaten to destroy public confidence in American made products. These are all critical issues, and restoring our initiative in manufacturing is a challenge of the greatest magnitude. Make no mistake about it; this will be no easy task.

Does H.R. 4415 provide the emphasis and wherewithal to meet this challenge? My answer to such a question is a qualified "yes," and it brings me to the second aspect of my remarks, namely my recommendations for implementing the "Purpose" of H.R. 4415. In my judgement, the purpose of this bill is well articulated, and the heart of the statement is found in two strategies - "To establish a program for conducting research which will produce more efficient manufacturing technologies and ----- to encourage widespread adoption of these technologies." This is a well intentioned statement; however, implementation of these strategies in order to meet the difficult challenges facing American manufacturing will require creativity and imagination coupled with a willingness to take some risk. I would ask you now to free your minds of past constraints and biases and think through with me what I consider the approaches which must be taken if the Bill is to be implemented successfully.

First of all, I recommend thoughtful consideration to be given to an implementation theme. In this regard, may I suggest the theme that manufacturing is a science not an art. Is this important? I think it is, and my judgment is that for manufacturing to make substantive progress beyond its current state of the art, we must make a transition in our thinking from manufacturing as an art to manufacturing as a science. Why do I think such a transition in thought is important? There are at least three reasons for my position. In the first place, it clears the way to focus on fundamental laws and issues of manufacturing for the purpose of understanding and planning. Secondly, it exposes the manufacturing process to fertile investigation using the powerful scientific method, and finally, defining manufacturing as a science permits the use of quantitative techniques that will in turn facilitate communication and implementation. So I would say to you that if this bill is to be successful, one requirement for implementation relates to theme. I recommend the theme that manufacturing is a science not an art.

A second recommendation, I would offer for your consideration, pertains to approach. I strongly suggest that the approach to be taken in implementating H.R. 4415 is to define manufacturing in terms of systems not components. It is my judgment, and it is one shared by others that manufacturing has gone about as far as it can go using the "piece mill" approach which serves only to analyze and solve component problems. Continuing in this vein will result, at best, in only small increments of progress, and the anemic condition of American manufacturing today requires much more. Manufacturing breakthroughs are needed in order to "leapfrog" foreign competition and return American manufacturing to its proper role of international leadership.

In my professional opinion, substantive changes can now occur only as a function of how well we are able to configure the manufacturing process as a system, and at the same time how effectively we are able to employ systems technology to examine the manufacturing process. Do we have the technology to accomplish this? Not altogether, but we do have sufficient technology to do a better job than we are currently doing, and I refer specifically to such technologies as simulation techniques, decision support analyses, integrated computer-aided manufacturing technologies, artificial intelligence concepts, etc. Obviously, gaps in our technology exist, and others will become apparent, but these gaps merely become problems for eventual research solution. Implementing H.R. 4415 will require a creative approach, and I recommend the approach that defines manufacturing in terms of systems rather than components.

Identifying an appropriate goal is a third consideration in implementing the purpose of H.R. 4415. In this regard, I would recommend that the goal should be to change manufacturing not just improve it. Some people may disagree with this goal, but such a disagreement is not likely in this audience. Obviously, we all recognize there is a need for some immediate improvements; however, immediate improvements are frequently short term in nature serving the purpose of a "bandaid" when in fact the wound requires major treatment. Although there is a risk, it is my judgment that we need to set our goal high because we must achieve more than short term improvments. In this sense, it should be stressed upfront that we have no real desire to just improve upon current ways of doing manufacturing. The goal, and lofty it is, should be to drive manufacturing thinking to its limits, and to become the preeminent international force that transitions manufacturing into the twenty-first century. Although I will mention some background to this position, I will not labor these points before this audience. I think that we are all in agreement that by in large, we are currently accomplishing manufacturing pretty much the way it was being done in the late 20's, 30's and 40's, and this is indicative of the fact that manufacturing today is outmoded and outdated. Even the "go words" we use to discuss what we call "modern manufacturing", i.e., such terms as integration, automation, group technology, cells, etc., are little more than efforts to "tweek" old methods. I do not mean to deny that these have brought improvements, but the fact is we have generally done nothing more than automate and computerize existing equipment and processes. This implies to me that manufacturing is still pretty much business as usual. So I would repeat for emphasis: Our goal should be to change the way we do manufacturing not "tweek" old methods. We will leave this short term approach the to the foreign competitors. After all, some have already been quoted as saying that they have nothing more to learn from us now. Appropriate implementation of H.R. 4415, I think, will not only prove this statement to be incorrect but also embarrassing to the one who made it.

A fourth recommendation I would make relates to implementation objectives. I seriously doubt that my recommendations in this case will come as any surprise to this audience, given the Congressional ground work and testimony that has already taken place with reference to H.R. 4415. The objectives, I recommend, are as follows:

(1) To stimulate and conduct original research in manufacturing systems.

(2) To promote manufacturing systems education in the academic environment by impacting university corricula in engineering as well as business.

(3) To transfer in timely fashion manufacturing systems technology to the industrial community.

Finally, I recommend that for the implementation of H.R. 4415 to be successful, it must have a well defined product focus. The correlation between product focus and success has been demonstrated historically. Where there has been product definition in the past, Federal efforts have achieved high rates of success, but in situations where such definitions have been missing, the results of Federal efforts have been less than desirable. So in this regard I would suggest that H.R. 4415 be implemented to produce the following:

> Computerized mathematical methodologies applicable to the analysis, design, and control of manufacturing systems to produce products from concept through production to introduction in the market place for profit.

A reasonable question in this regard is what about the development of equipment technology. Again, my feeling is that new equipment technology will be a natural beneficial biproduct of implementation. My judgment is that when creative individuals from several technical disciplines interact in a research and development environment, beneficial biproducts will naturally and necessarily result. One of these will be new equipment technology. However, it should be recognized that equipment technology is not one of the defined products of implementation, and in my opinion the specific aim to develop new equipment technology should be left to the manufacturing industries. But in this regard, I would caution them about the need to change manufacturing for the twenty-first century, not to improve or "tweek" the current manufacturing methods that are so closely dependent on the 20's, 30's and early 40's.

Let me close with some brief comments regarding organization, an aspect that will certainly be vital in assuring the successful implementation of H.R. 4415. Implementation in my judgment should take place in university environments where counterparts from universities, federal agencies, and American industries can come together in cooperative partnerships. At least two things make this approach desirable. First of all, Advisory Boards could be formed with representatives from the three cooperating entities, and the Advisory Boards could in turn provide research direction to the university.

Secondly, university environments will provide access to the widest range of technical skills and professional backgrounds of faculty as well as the intellectual vitality of young graduate students. Organizational implementation in a university environment, in my judgement, would certainly increase the probability of success of the of H.R. 4415.

The foregoing represents the substance of my thoughts. May I say again, I appreciate the opportunity to add my support to H.R. 4415, and I would repeat again for emphasis that implementation is now the key to success. In this respect, considerable attention must be given to such items as theme, approach, goal, objectives, products, and organization. My recommendation regarding these items are respectively submitted.

Comments on Proposed Legislation to Support Research and Development on Automated Manufacturing (HR 4047 and HR 4415)

Jerome A. Smith
Industrial Technology Institute

Introduction

It is indeed a pleasure and an honor for me to be invited today to provide some comments on two bills which are under consideration by your committee. My remarks will address HR 4047, the Robotics and Automated Manufacturing Systems Research and Education Act of 1983, and HR 4415, the Manufacturing Sciences and Technology Research and Development Act of 1983. These two bills have very similar goals, and many of the proposed mechanisms for stimulating research and technology development are the same. My overall conclusion is that this nation probably does not need both of these bills, but passing a bill to support research and development related to automated manufacturing process technology is absolutely essential.

My purpose in coming today is three-fold. First, I will provide some additional reasons for passing legislation for federal support of research and development for manufacturing technology which are not cited in either proposed bill. Second, I will briefly describe the Industrial Technology Institute, a newly formed organization which can serve as a role model for the type of institution which the legislation should support. And, third, I will offer some suggestions for a bill which will combine the best parts of both of the proposed bills with some additional considerations or constraints to be placed on the funding in order to maximize effectiveness.

Justification for Federal Support

All of the "Findings" cited in HR 4047 and HR 4415 accurately depict the situation with respect to manufacturing technology in this country: that is, the existence of foreign manufacturers that have demonstrated superior productivity on the basis of advanced manufacturing technology implementation cannot be denied. Also, the availability of technology derived from defense, space, and communication applications gives us insight on possible productivity improvements and the need for additional research and technology development. These two factors argue strongly for this society to allocate resources to improve manufacturing productivity. A fundamental question arises--Why should support for research, development, and technology application for manufacturing be provided by the federal government? Let me attempt to give you some justification.

First, the health of durable goods manufacturing is a national issue. Durable goods with sales of $549 billion accounted for 17% of last year's Gross National Product. Manufacturing capability has long been and will continue to be a vital element of national security. Thus, from both economic and national defense points of view, it is essential that we preserve our leadership in durable goods production. Second, it is unlikely that either state or local government will devote the resources required. In many areas where the impacts of foreign competition have been felt most acutely, local government resources are most strained, and state and local governments do not feel that research and development are a major element of their missions. Significant initiatives have been funded by states such as New York, Pennsylvania, Ohio, and Michigan. However, in aggregate these commitments provide less than is identified as one year's funding in HR 4047 or HR 4415; that is, while these are important, they are inadequate. Third, the talent pool for addressing manufacturing technology problems is extremely thin. This derives from the gradual decline (that this country has experienced over the past thirty years) in engineering school faculty and student populations devoted to manufacturing technology. This is due in part to the absence of any significant federal funding for sponsored research in these areas. Another factor is a consequence of a value system for faculty selection/promotion and curriculum development which emphasized applied science at the expense of applications oriented systems development. These trends are beginning to be reversed, but federal research funding will accelerate the process and provide focus and direction to the kind of multiple-discipline research and education that is required.

We cannot expect industry to provide the resources for manufacturing process research and development. In basic research the federal government accounts for 75% of the total, according to data gathered by the National Science Foundation. The rest is provided by industry, universities, state governments, and non-profit institutions. The industrial contribution is heavily concentrated in the pharmaceutical and electronic industries. In applied research and development, the industry share is much more significant, 55% of the total. However, the vast majority of this investment is devoted to product development (75%) as opposed to process development (13%). (Twelve percent of industrial research and development cannot be classified into either product or process development, according to NSF's analysis of 1981 data.) The emphasis on process development is much higher in chemicals, textiles, and food production. Therefore, investments by the durable goods manufacturing industries can be estimated to be a smaller fraction, perhaps 5-10%. The point is that there is very little by way of tradition that argues that durable goods manufacturers will devote significant resources to process development. Furthermore, federal funding for manufacturing process related research and development will ensure more rapid dissemination and widespread utilization of the technology than would result from industrial investments.

Another major argument against any statement that industry can do the job derives from the demographics of manufacturing firms. The bulk of durable goods manufacturers are relatively small firms with virtually no in-house capability to perform research and development. For example, in the metal working industries (those with SIC codes 33-39) there are 67,800 establishments with manufacturing at a location with 20 or more employees. Of this number only 2,400 have more than 500 employees. Sixty-three percent, or more than 43,000, have fewer than 100 employees. Thus, manufacturing in this nation is performed by a very large number of relatively small firms. It is a very safe conclusion that these small firms do not possess, nor can they afford, the technologically sophisticated staff required to perform process related research and development to remain competitive. Furthermore, it would be terribly inefficient for them to try to do so, and the required talent base simply does not exist.

These statistics may be a key to understanding the vulnerability of today's manufacturers with respect to much larger foreign-based, multi-national competitors. While smallness was a virtue in developing a responsive, innovative supplier base for larger equipment manufacturers, it makes it difficult to address the spectrum of technologies that will be required for the factory of the future, e.g., computer-integrated sensors and machines, digital communications, and software which will control processes, inventory, and business systems.

There are two fundamental elements in the quest for improved manufacturing productivity. One is the development of new technology to automate processes. The other, equally difficult, is transferring this technology to actual application. As evidence of the latter, consider two factors. First, after twenty-five years since development of the technology, less than 10% of the machine tools used in this country are numerically controlled. (Incidentally, my Institute recently tried desperately to buy an American built numerically controlled lathe and could find no source which could match the price and capability of a foreign built machine!) Second, we have seen several recent examples of basic research results developed in this country which have led to first or superior applications in the hands of foreign competitors, e.g., silicon carbide yarns, diode lasers, fiber optic cables, to name a few. My observation from almost five years of government service in the leadership of a government research funding agency is that we have too few mechanisms in our society devoted to application development and technology transfer. In those arenas in which such mechanisms exist, e.g., defense, medicine, and space, the translation of research results into application has been fairly effective and our world technological leadership is seldom questioned. Therefore, it is essential that you pass legislation that will enhance both the generation of new knowledge through research and the transfer of that knowledge through applications development in order to be used by this nation's manufacturers.

The Industrial Technology Institute

Visionary leaders in Michigan have recognized both of these fundamental elements in founding the Industrial Technology Institute, which I represent. The Institute is destined to become a world-class research and development organization devoted to addressing the obstacles to the realization of computer-integrated manufacturing. Incorporated in December of 1982, and initially capitalized by grants from the State of Michigan and the Kellogg, Dow, and Mott Foundations, this organization was conceived to have several roles and functions. These include: (1) performing both basic and applied research in the areas of industrial automation and computer-integrated manufacturing

- concentrating on both the technological as well as the social and economic implications; (2) developing new techniques, sensors, algorithms, processes and decision-making tools for implementation in the factory of the future; (3) disseminating information on emerging automation technologies, social impacts, and economic analyses generated both within and outside the Institute; and (4) fostering the development of a new industry devoted to the production of hardware and software for automated manufacturing. Thus, the mission of the Institute is to perform as both a generator of new information and an information transfer agent for automated manufacturing. It is positioned organizationally as a publicly supported, non-profit corporation, and, programmatically, as a performer of applied research and development, at the interface between academic research and industrial implementation. Technology transfer and modification of the social, management, and organizational framework for manufacturing are perceived as being as challenging and as difficult a problem as technological innovation. Institute staff transfer information by acting in a variety of roles: as contractors or collaborators with industrial partners; as consultants to industrial clients; as publishers of reports, journal articles, and books; and as instructors for short courses or participants in workshops.

The Institute is located adjacent to the University of Michigan's College of Engineering and in the midst of an extensive manufacturing community-there are over 7,000 manufacturing firms within a 100-mile radius of Ann Arbor, and Southeastern Michigan is within 600 or so miles of consumer-product markets comprising 50% of the total population of the U.S. and Canada. The organizational structure and goals of the Institute meet all the stipulations of a "Center for Industrial Technology" described in Section 3705 of the Stevenson-Wydler Technology Innovation act of 1980 (which has yet to be implemented with any significant resources from the federal government.)

The Institute's technical programs address the problems of digitally controlled sensors and machines. The software for control of both the hardware and the communication networks represents a substantial part of the effort. In addition, new software for integrating design, planning, procurement, and operations scheduling is required. New sensors and mechanical devices will be required to perform manufacturing processes such as assembly and monitor system performance. In many instances the effort will focus on the adaptation of existing concepts to new applications. In others, new approaches will be required.

There are social and economic obstacles lying in the path as well. One component derives from the organizational structure of manufacturing which has evolved to focus the activity of human labor. Not only will the organizational structure require change, but the nature of human labor will be modified. Control of information, its dissemination and its modification, will pose many new problems which are inseparable from both the organizational structure and the nature of the technology. Economic models are required which emphasize the costs and benefits of product quality, flexible use of capital equipment, reduction of inventory, and repair and maintenance of electronically sophisticated tools. Accurate projections of future impacts on work force size, structure, and necessary skills can hasten the transformation of durable goods manufacturing by informing government, labor, and management leaders of the impending changes.

The Institute is being structured to address not only the many technological and economic barriers to creating integrated manufacturing installations, but two very significant cultural barriers. The first of these is the unnaturally long time that it takes for results from basic research to be put into application. With the exception of a few professional societies and industrial research institutes, there are very few mechanisms for technology transfer in the manufacturing arena. Until the past few years, no long-term federal support has been available for this kind of technology development. Manufacturing has traditionally been viewed as a segment of the society that could fend for itself. It is the relatively recent incursion of foreign suppliers into capital-intensive areas like steel, ship building, automobiles, and electronics that has called this assumption into question.

The second major cultural barrier is that, with few exceptions, implementation of technologically sophisticated manufacturing equipment requires relatively large amounts of capital as well as a new way of conducting business. This creates the kind of individual risk for engineering design and manufacturing production staff previously encountered only in marketing departments. It creates the need for new tools to assess the benefits and implications of the introduction of new manufacturing methods. By orienting our staff to focus on more applied, systems-integration problems, by creating facilities to provide working test beds for integrated manufacturing, and by addressing social, organizational, and managerial problems, the Institute intends to reduce the risk involved and hasten the implementation of automated manufacturing technologies.

The Institute has acquired a staff of more than forty people in the past year. Plans call for a total of 75 personnel by the end of 1984 on the way to developing a 250 person organization by 1988. Already the Institute has developed collaborative relationships with faculty and students from five universities, and several initiatives are underway to develop cooperative programs with industrial firms which have been eager to see the formation of this unique enterprise.

Future growth of staff and programs is predicated on the availability of funding from industrial and government sponsors. Industrial sponsorship from large manufacturers seems assured. However, as I described above, there is a question as to whether small manufacturers have the will or the resources to devote to sponsoring the research and development projects necessary for their survival and growth. Expanded federal support, therefore, is imperative.

A Proposal for New Legislation

Present federal funding for manufacturing related research and development is woefully inadequate, restricted to a $5 million National Science Foundation program and some smaller efforts in other agencies such as the Office of Naval Research and the Air Force's ICAM project. Most of the funds expended by the military departments' manufacturing technology programs are devoted to small batch, military production problems, and the work is being performed by their industrial contractors. There is a need for a much broader base of federal support which addresses the problems relating to mid and high volume commercial product manufacturing.

Let me make some specific comments with regard to the two bills, HR 4047 and HR 4415, which are under the consideration of this committee. First, I am not certain that both are needed. The level of effort provided by the successful passage of both bills could not be provided by the existing talent pool. If asked to pick one bill over the other, I would endorse the passage of HR 4047 for three significant reasons. First, it provides a longer term base of support, extending to 1990. This is important because development of advanced manufacturing technology is not a short-term proposition. The breadth of technology required is extensive and the integration problems are extremely complex and will demand extensive effort for a decade to provide the tools as well as the trained manpower to use them effectively. Second, HR 4047 explicitly provides funding for a federal research center at the National Bureau of Standards. Activity at NBS is already underway and has served to transfer technology and focus on questions of standards which are important factors in making further progress. Third, HR 4047 calls for the establishment of both Centers for Industrial Technology as well as a more broadly based basic research program and accompanying graduate fellowship and training programs to be implemented in universities and colleges. Thus, HR 4047 correctly identifies the importance of technology applications development as well as new fundamental knowledge generation.

This is not to say that I feel HR 4047 is perfect. There are modifications to the bill which I would ask you to consider. For example, Section 8 stipulates lump sum funding for implementing Sections 5a and 5c, $20 million in FY84, 40 million in FY85, and $50 million/year in FY's 86-90. To ensure the establishment of and adequate funding for Centers for Industrial Technology, specific funding or a minimum level of funding should be explicitly stated in the bill for Section 5a. I would argue for the eventual establishment of five or six such centers, each funded at an annual level of approximately $5 million. Thus, Section 8a could be modified to stipulate that $10 million be provided in the first year, $20 million in the second year, and $25 million each year thereafter for the establishment and sustaining of programs at no fewer than five Centers for Industrial Technology. Section 5c would be funded by the balance.

Another suggested change would be to eliminate the phrase, "a discrete segment" in Section 5(a)(2) of HR 4047. As stated, centers would be established to focus research and development on very narrow segments of the automated manufacturing problem set. This would be a mistake, in my opinion, because one of the most difficult tasks in achieving computer-integrated manufacturing is tying together the sensors, digitally controlled machines, and communication networks with the software for integrated control. Furthermore, integration of the hardware and software systems must be performed with conscious knowledge of its impact on the organizational structure and manner of conducting business in manufacturing firms. For these reasons, I recommend that the language reflect a desire for the establishment of a series of multi-disciplinary centers which devote attention to several aspects of the technological and social impediments to achieving advances in manufacturing productivity.

As a minor addition, I suggest that a desire be expressed by the Congress that these centers be established with some view toward geographical distribution in areas which contain a significant manufacturing base. This provision would assist in technology transfer and the actual implementation of technological advances.

One difference that exists between HR 4047 and HR 4415 is the implementing agency. HR 4047 would make NSF the responsible agent for implementation, while HR 4415 gives the responsibility for carrying out its provisions to the Department of Commerce. While I understand the efficiency of single agency responsibility, it may be prudent in this instance to involve both the NSF and NBS in the management of this program. NSF certainly has the tradition and expertise to conduct the basic research (Section 5c) and training (Section 6) provisions of HR 4047. However, NBS, being designated as a federal research center (Section 5b), would be in an excellent position to maximize the effectiveness of the implementation of Section(5a). The National

Engineering Laboratory of the NBS has the talent and expertise to effectively manage and coordinate the programs of Centers for Industrial Technology to be established by this legislation, and the integration of these with the federal research center is imperative.

Conclusion

In summary, I have tried to supplement the strong case that already has been made in the language of these two bills with additional reasons for federal government support for research and development in automated manufacturing. Also, by my description of the Industrial Technology Institute, I have tried to convey that we have already established an organization which fulfills the objectives of the proposed legislation, and that this organization can serve as a role model for the creation of others. My comments on the specific provisions of the two bills are designed to ensure that attention is also paid to applications development and technology transfer as well as fundamental research.

Thank you for your kind attention. I would be happy to answer any questions you might have on the points raised here or on other aspects of the proposed legislation.

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before the

Subcommittee on Science, Research, and Technology
of the House Science and Technology Committee
U.S. House of Representatives
June 12, 1984

Mr. Chairman, Members of the Subcommittee, thank you for the invitation to testify on behalf of the IBM Corporation on the issue of the impact of technical innovation on U.S. economic competitiveness and the role of the federal government in the enhancement of the innovation process.

We in IBM are afraid that, sometimes, our views on the role of the government are discounted because we are seen as a successful self-sufficient multinational company who consistently advocates "laissez faire" policies. And while we make no claim to speak for anyone but ourselves, it is important to say that because we work with hundreds of small companies as suppliers (e.g., the IBM PC is almost entirely an assembly of components purchased from other companies), our views are inevitably influenced by our daily involvement with the details of technology transfer and commercialization among a representative group of both large and small companies.

Mr. Chairman, we are discussing a very broad subject and it is difficult to respond cogently without an attempt to put this issue into context. I offer the following statements on that basis.

There is general agreement that, since the 1960's, U.S. international competitiveness has on average declined. This has come about primarily because of strong and technologically capable competition, which has reduced U.S. trade shares overseas and is accelerating the effect of fundamental, systematic change in the U.S. economy here at home.

In evaluating the seriousness of the problems we face, it is important to be very objective about causes and very discriminating about cures. For the roots of the new competitive challenges from overseas are in the mastery by others of the very talents that made the U.S. economy the world leader in the past and sustain it even today as the most productive industrial economy in the world.

I do not want to suggest that we Americans don't face a serious challenge -- or to imply that we do not have serious structural problems that require government's attention. Indeed the budget gap, the overpriced dollar, an unacceptably low savings rate are all serious threats to our future competitiveness. I do want to suggest that macroeconomic arguments, which are essential guides to fiscal policy, are poor guides to science and technology policy.

For example, many say America is "de-industrializing," losing jobs in the manufacturing sector as a result of foreign competition. In fact, that is not so, either in 1950-73 or 1973-80. (1)

But even if that were so, you would not know whether the news was good or bad -- good because increasing productivity permitted a growing, competitive industry, whose growing revenues funded new jobs in services -- or bad because falling productivity resulted in lost sales and attrition of the work force into unemployment. Our technological problems need a microeconomic analysis.

The truth is the U.S. faces two tasks: first, to accelerate our ability to develop new products and services, and the new technologies that give them superior prices, quality and value; and second, to enhance the agility and compassion with which our society embraces structural changes from which our people will benefit in the long run.

We must learn to do better what we Americans already do very well. This is not cause for complacency. Neither is it cause for a crisis level of alarm, precipitating ineffectual actions.

The realization that our most rapidly growing industrial competitors are Japan and its East Asian neighbors Korea, Hong Kong, Taiwan,

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(1) Robert Z. Lawrence, "Changes in U.S. Industrial Structure: The Role of Global Forces, Secular Trends and Transitory Cycles," prepared for the Symposium on Industrial Change and Public Policy, Federal Reserve Bank of Kansas City, August 1983, p. 8.

and Singapore and an analysis of the industry segments in which they have gained shares does support the proposition that the U.S. ability to commercialize new ideas as rapidly as is necessary has decreased even while our ability to generate new ideas remains strong.

It is to this problem of commercialization of technology that we understand the proposed solutions contained in the bills before this Committee today are directed and to which our views are addressed.

At the risk of oversimplification, let me characterize these bills in three groups:

> H.R. 2525 and 1243 propose two different mechanisms for developing a national industrial strategy.
>
> H.R. 481 and 4361 (along with it's companion H.R. 4360) propose new government agencies to take actions in implementation of such a strategy.
>
> H.R. 4047 and 4415 are aimed at enhancing capabilities in one specific technical area: manufacturing systems.

Without getting into the details of these measures, we can identify two basic themes underlying all of them:

A. To what extent should the federal government attempt to define, influence or direct the private sector's plans or actions in commercial technology?

B. To what extent and in what manner should federal agencies select and finance technical activities -- research or educational -- intended to enhance commercial competitiveness?

If the choices open to us in answer to these questions were limited to "in every way" or "never," the debate would turn on very simple issues -- a choice between state socialism and unconstrained capitalism. Happily, a much more sophisticated set of choices are available to us -- for there are both appropriate and inappropriate roles for government in this area.

The rhetoric used to get this issue of technological vitality in our economy on the national agenda too often obscures the criteria that should guide policy. Thus, while IBM favors strong federal actions that make important contributions to that vitality, we oppose many - though not all - of the solutions suggested in these bills.

Let me now address in some detail the criteria for federal action that we believe should guide public policy. You will see that we strongly endorse much that this committee and the agencies it authorizes do, and we feel that many of the future actions of government can best be carried out through those same agencies and in the same tradition of non-coercive cooperation among government, industry and education, and vigorous competition in a free market place.

TECHNOLOGY PROMOTION AS AN ELEMENT OF ECONOMIC POLICY

Given the fact that high on the public agenda is concern for U.S. economic competitiveness, whose roots lie in the capacity of the private sector for productivity growth and technological innovation, the question before us is What actions should the federal government take to promote the technological capabilities and hence the competitiveness of U.S. firms?

I will make the case that government must strengthen and sustain three close relationships in our technological infrastructure; the relationship between advanced research and higher education; between science and engineering; and between universities and industry.

The mechanisms through which industry gains access to talent and new ideas are as varied and complex as the innovation process itself. However, much one wishes one could short-circuit this complexity by direct federal investment in specific commercial technologies, that strategy will usually be a failure.

Thus, we favor keeping federal support for science and universities strong, encouraging the expansion of NSF's activities in academic engineering, and encouraging collaboration between universities and industrial companies of all sizes and kinds.

We do not favor separating engineering from the NSF or the creation of new agencies that could divide rather than unite our national technical community. Both H.R. 4361 and 481 could have this effect. Much of what should be done can be accomplished under the NSF Enabling Act and the Stevenson-Wydler Act. The amendment to the NSF statute passed by this committee, while probably not necessary, helps to make clear that NSF's mission covers the full spectrum of skills and creative pursuits needed for a productive, innovative society. I urge the Congress to move ahead with the structure we have, challenging both NSF and the Department of Commerce to strengthen their capabilities and work with industry in ways both communities will find beneficial.

TECHNOLOGY, SCIENCE AND THE INNOVATION PROCESS

To explain my point of view, let me begin with a short comment on the nature of the industrial innovation process. Industrial and indeed, agricultural and service firms too, depend on technology to insure good quality and low cost for their products - in other words, to increase their productivity and competitiveness.

Better technology and innovative ideas are also the keys to new products and processes and, thus, to innovation and business growth. Technology is, therefore, a capability - made of science and engineering knowledge, skills and experience deployed in a competitive environment for the production of goods and services. Technology is not science, is not information, is not research. Technology is, of course, the main product of industrial research, engineering and entrepreneurial management. But to be competitive, commercial technology must be developed by people with an intimate knowledge of both market circumstances and cost implications. This knowledge must be timely, for daily decisions on technical strategy are influenced by changing competitive circumstances, new reports of scientific progress in the universities, new implications for production costs and schedules as engineering data are gathered.

Any commercial laboratory that is not highly responsive to these changing circumstances runs the danger of developing the wrong product for the wrong market, out of the wrong technology at the wrong costs. Few people in government have either the information or the management environment required to operate a program of technology development for commercial use.

These dynamics of industrial R&D are especially important in "high tech" industries where change is particularly rapid. Our company, for example, is working concurrently on six generations of computer systems, each with technology with roughly twice the effectiveness of it predecessor. But the historically more slow-paced industries (some even doomed to the designation "sunset" industries) are also challenged by rapid technological change, for the new industrial technologies of automation and information management can be used - and are being used by U.S. competitors - to upgrade both productivity and product at a rapid pace in these industries too. Industries where fixed costs are high and plants are old must be particularly adroit in making technology choices. I don't believe government agencies should try to make those choices for them, and thus am very skeptical about the applied commercial research proposal in H.R. 4361.

In contrast to commercial development of products and technology, scientific and engineering research is typically aimed at exploring the art of the possible, at testing potentially valuable but high-risk ideas whose payoff lies out in the future, at exploring new tools and methods. Strategic judgments on research directions depend on deep understanding of both science and the processes by which the science may later be put to work. Industrial and academic scientists and engineers share the necessary knowledge and experience to make these judgments and contribute to the foundations for new technologies. This is the kind of work NSF and other agencies do and should support - both in science and in engineering.

Since commercial technology draws so directly on scientific and engineering research and the education of the nation's pool of scientific and engineering talent, the ability of private companies to innovate is directly dependent on the vigor, availability and appropriateness of these knowledge and human resources. For this reason, we strongly support the policy of focusing government sponsored long range research primarily in college and university laboratories.

SOME POLICY PRINCIPLES

The role of government, then, is to:

(a) remove obstacles to innovation and productivity growth,

(b) provide an economic, tax and regulatory environment conducive to technological advance,

(c) support the human resources and research base for the technologies on which the private sector depends.

In addition, of course, government also has constitutional obligations:

(d) at the federal level, to invest in military, space, public health and safety, and other federal R&D needs and

(e) at the state level, to sustain the system of public schools, colleges, universities and state research institutions on which the local economy, health and welfare depend.

How, should the federal government decide more specifically what activities it should undertake? We believe the following principles should apply:

(a) Government should assure the health of both the environment and the process for private innovation, and not substitute itself for the more effective private sector process of technology generation. Government officials are too far removed from the short-term vagaries of the marketplace to be sufficiently sensitive to these subtle and often decisive influences. The time constant for change in direction in government-directed work is much too long. Thus, the test for federal funding of R&D aimed at benefits to civil employment and economic competitiveness should be: Is detailed, first hand knowledge of competitive market conditions and requirements for production and service necessary to make the R&D useful and competitive? If so, government should restrain its zeal to help in this manner.

(b) Many economists argue that individual firms tend to invest less in R&D than would be of greatest benefit to the economy as a whole, because only a part of the benefits are appropriable by the investing firm. Thus, government has an incentive to encourage expanded investment in commercial R&D. To do so directly, by government selection and funding of industries and commercial projects, would in most cases incur the problem just discussed. Instead, government should use the incremental R&D tax credit as a means for encouraging expanded private investment, not the selection by government of specific commercial projects for support.(2) H.R. 4475 and S. 2165 would make the tax credit permanent and tighten its definitions.

(c) There are technologies of potentially very great commercial value, which are so long delayed in possible commercial benefit and so risk-sensitive that private investment is unlikely to respond to the opportunity. In these circumstances, federal participation may be warranted. For such technologies markets may not yet exist. The problems are primarily technical. Examples might include the early development of nuclear electric power technology,.early development of new types of large commercial aircraft and space technology investments that led to commercial communications satellites. In the nuclear power case, the government owned the technology initially and its role was important, but government domination of the industry's technology probably persisted much too long. In special circumstances, where a radically new area of science and engineering gives promise of great, but distant, economic potential, and private capital cannot be expected to respond, federal support for the exploratory phase of the technology may be appropriate. Government should also learn how to get out of these areas and turn back to fundamental research and generic technology at the right time.

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(2) See Direct Tax Incentives for R&D: Time to Cut Bait or to Fish? by Lewis M. Branscomb, IBM Corp., Harvard Business School 75th Anniversary Colloquium on Productivity and Technology - March 28, 1984

(d) A closely related case is the federal demonstration project. Often expensive projects like the SST, HUD's "breakthrough" project on modular housing, or the Clinch River Breeder are proposed as tests of either the technology or the market or both. Costing tens or even hundreds of millions of dollars, they become too conspicuous to permit much technological risk, and they rarely test realistic market or economic conditions. This form of federal development program has lost favor over the last two administrations, and has to a large extent been eliminated from the non-defense sector of the federal budget. Federal demonstration programs that test neither technology nor market acceptance and economics should not be undertaken.

(e) Sustaining the vigor and accessibility of scientific and engineering research and education is a clear federal responsibility, shared with the states and private institutions. U.S. science is the envy of the world, honored by a lion's share of Nobel prizes and followed in great detail by nations less well endowed with scientific imagination and accomplishment. A bountiful source of ideas for technologies of future long range non-proprietary scientific and engineering research must be sustained in its world leadership position by federal funds. The National Science Foundation and the National Institutes of Health are well suited to these tasks today.

(f) Many industrialized nations support their post-graduate and professional schools through ministries of education, and fund research through a system of national laboratories. This pattern is seen in Germany (Max Planck Institute), France (CNRS), Japan (MITI laboratories), Australia (CSIRO) and the USSR (Soviet Academy). Much of the quality of U.S. higher education and the relatively close and supportive relationship between our universities and industry result from a unique policy that should be continued: Focus the majority of federal basic research funds in U.S. university laboratories, thus sustaining both education and research through a single pattern of investments. This greatly enhances the value of the research investment to industry, for the most effective means for transfer of research knowledge is through the employment of people with research experience.

(g) Only 7 % of university research is supported by private industry - a measure of the distinct roles these institutions play in the national scientific enterprise. Only 3 % of the total funds available to private research universities comes from corporate philanthropy. Yet these relationships are very important as means for keeping private companies in touch with new ideas and exposing students and faculty to the priorities and challenges of private industry. Government policies that encourage companies to assist and collaborate with universities leverage the federal research investment and pay important, if unquantifiable, economic dividends. Tax policies encouraging industrial gifts of modern equipment and support for research in universities are a good mechanism, for initiative and accountability remain with the colleges and companies. H.R. 4475 and S.2165 would accomplish this objective. Equally important is generous federal support of university research in areas such as the materials sciences, information sciences, engineering sciences and useful but basic studies in all disciplines, so the universities can attract and sustain those capabilities with which industry will most want to collaborate.

FEDERAL SUPPORT FOR FUNDAMENTAL RESEARCH OF NEAR-TERM UTILITY

Research in such useful fields of science or engineering can have a pervasive and often immediate utility in private industry. It is more practical as a basis for university-industry collaboration than the equally important domain of federal support for "basic" or fundamental academic research and will attract more smaller companies. It is more acceptable and effective than the funding by government of commercial, proprietary research (which I have argued is usually ineffective and inappropriate). Such research offers educational and intellectual challenge and is not product specific. It is useful yet fundamental research. It is often multidisciplinary. Other examples might include research on ceramic or polymer materials, numerical analysis and computational science, instrumentation and meteorology, quality and failure analysis, computer-aided design and manufacturing, and robotic systems research.

Such fields are areas of primary interest to industry, yet they are also appropriate for research in the course of graduate training. The concept that certain areas of fundamental, non-proprietary research can also be very useful aids to productivity growth is well known in agriculture, pharmaceuticals and other industries, too.

University scientists pursue such fields primarily for their intrinsic scientific interest, but, if they are in touch with their peers in industry and if funding is available from federal agencies for such basic work, the universities can make a strong and highly acceptable contribution to industry and to the economy.

Historically, the Department of Defense and other "mission" agencies have provided support for these fields of "useful" science and engineering, along with the National Science Foundation and important but small amounts of support from industry. Unfortunately the breadth and depth of agency support of such work has declined as more emphasis has been placed on more applied work of narrow agency interest.

The industrial technologies on which congressional attention has been focused -- microelectronics, robotics, super-computers, bio-engineering, materials engineering -- are most effectively stimulated by federal support of this kind of university centered research, conducted with the participation of private industry. Many opportunities for beneficial expansion of this kind of work exist.

Stevenson-Wydler Technology Innovation Act

The Stevenson-Wydler Act (PL 96-480) is the primary statute for federal promotion of industrial technology in the U.S. and it provides an adequate authority for this kind of useful research. Its provisions envisage the establishment of "Centers for Industrial Technology" (CIT's) at universities and at other not-for-profit institutions as means for improving the utilization of federally funded research and the promotion of technological development. The law identifies "generic research" projects as the appropriate kind of work to be undertaken at these centers. Cooperation and participation by industry is part of the scheme.

A number of such centers have been established by the National Science Foundation. However, the NSF centers do not develop commercial technology, as defined in my introduction. Indeed, the NSF calls them "university-industry centers" and wisely refrains from suggesting that they engage in "industrial technology" as defined in the Act. The NSF has, for example, initiated modestly-sized but excellent centers in the fields of polymer science, ceramics and electronic materials at universities. Industry participation has grown to the point that these centers are now 70 to 80% funded by private industry. The federal funds which initiate them are essential, for no one company can support a large enough program to stand on its own. As is typical of university programs, the work is non-proprietary and is intended for publication.

While the NSF university-industry centers are consistent with the Stevenson-Wydler Act mandate, the Department of Commerce - which is the lead agency for the Act - sought and obtained the approval of Congress in 1981 to rescind appropriations for establishment of CIT's under the Department's sponsorship. The rationale for this decision is given in a recent report to the President and Congress, as required under the Act. The Department was evidently reluctant to proceed with activities under the words "centers for industrial technology," which convey a purpose and program far from the reality of what the universities and industry scientists are prepared to do and whose implications would make many business people uneasy.

An interdisciplinary university laboratory - with visiting staff from industry - performing publishable research on colloid chemistry, for example, is not likely to engage in the development of commercial technology and should not be expected to do so. The university culture will emphasize more fundamental and speculative problems. The industry scientist involved will not want to expose their proprietary secrets to their competitors. The inflated expectations inherent in the congressional language of the Stevenson-Wydler Act is incompatible with the more basic and generic kind of work that emerges when university and industrial scientists collaborate. A substantial expansion of university-industry collaborative research, with federal support primarily for the university's participation, in fields of mutual interest and of a non-proprietary character could be of great value throughout industry.

Engineering research as well as science should be included to insure that smaller companies without research laboratories will be aided in their quest for higher productivity based on state-of-the-art manufacturing processes and materials. The Fraunhofer Institutes in Germany provide another interesting example of such institutions. The Stevenson-Wydler Act provides adequate authority - as does the NSF enabling statute - but it should be amended to modify the expectations stimulated by its language and funded to support university-centered work, carried out in collaboration with industry.

Production and Design as Technological Challenges

An area for federal investment in education and research of great importance to the economy is in science and engineering and relates to the functions of design and production.

Where the Japanese have an industrial advantage, it is more often in production and in rapid reduction to practice of science than it is in innovation and development. As noted in the study by the President's National Productivity Advisory Committee (NPAC), U.S. schools of engineering have since, World War II, emphasized research and development skills, not production and design. Their research support came primarily from the defense, space and other "federal mission" agencies. Stressing the art of the possible took precedence over engineering principles aimed at quality, cost and utility. The results were spectacular, as seen in the Apollo program, but at the cost of diverting talent from the production function (except, perhaps, in chemical engineering).

At the same time, Japanese engineers were focusing on high quality and low cost as competitive advantages, and developed management, design and production strategies enabling them to minimize the time required to adapt inventions and discoveries of other countries into products for export.

U.S. industry has risen to the challenge, and the burden is falling on the new generation of engineers. It is essential that the challenges of efficient production and design for manufacturability attract their rightful share of the most technically talented students. Fortunately, the intellectual excitement of robotics, computer design graphics and bio-engineering are a powerful magnet for students and faculty alike. A $50 million challenge grant of equipment and funds for educational development made by IBM has helped over two dozen universities initiate new programs and educational reforms.

A similar revolution in engineering is taking place in the field of materials engineering and in the role of computers as simulation tools, making unnecessary the time-honored practice of "bread-board" testing of new designs before commitment to production.

As a result, the National Science Board, the National Academy of Engineering, the engineering professional societies and the schools of engineering are eager to upgrade and modernize U.S. engineering capabilities. Making this happen must receive a very high priority in any plan to improve productivity and promote innovation in the domestic economy.

However, the financial resources are not in sight to make a major beginning, even though the private sector has already provided major support and the Administration's FY85 budget contains a small ($20 million) initiative to this end in the NSF engineering program. Three areas of greatest priority are (a) modernization of university research and instructional equipment, (b) curriculum and program reform - both across the conventional disciplines and in joint programs with industry and (c) support for graduate students and young faculty in the new areas where competition for their services in industry is especially keen.

H.R. 4047 addresses these issues, although its definition of "automated manufacturing system" is much too narrow. It has the virtue of working through existing agencies - NSF and the Department of Commerce - and is superior to H.R. 4415 because it includes emphasis on engineering education and not just research. We support the purpose of H.R. 4047.

ORGANIZATION AND MANAGEMENT OF THE FEDERAL R&D ENTERPRISE

There is no focal point within the executive branch for monitoring the effect of the total federal R&D activities on the private sector's technological capabilities, or for generating the policy analysis for maximizing the economic value of this $50 billion annual investment.

The Office of Science and Technology Policy (OSTP) in the Executive Office of the President does not have the resources; the Department of Commerce looks primarily to its own activities. In any case, in the most recent reorganization proposal affecting Commerce the original plan was to divest the remaining scientific bureaus from the Department should the Department of International Trade and

Industry be created. H.R. 481 would also deprive the Commerce Department of most of its technical capability. We would prefer to see the Department improve its capability to understand the technical aspects of microeconomic analysis, rather than dismember it.

A number of the policy objectives advanced in this paper call for the ability to look at the programs and the institutions for R&D across the government, including the Department of Defense as well as civil agencies, national laboratories as well as university support programs.

Both H.R. 2525 and H.R. 1243 make provision for the fact gathering and microeconomic analysis that is needed. Rather than doing this work under a National Commission, as proposed in H.R. 2525, we prefer to see the Department of Commerce increase its skill and experience in science, engineering and microeconomics. The National Research Council can certainly help bring the experts togther for similar purposes, as proposed in H.R. 1243.

But our serious objection to both these bills is they do not stop at research and information services. They call for the generation of national industrial strategies for which neither the NRC nor the proposed Commission would have the skills, experience or information to be of any real help to private industry. And if agencies then attempted to translate these strategies into commercial reality, the distortion of the private sector's, freedom of action could become a serious inhibitor to competitiveness.

MATCHING RHETORIC TO REALITY

Much of the current conflict over proposals to invest federal funds in R&D activities to support economic performance is a consequence of a serious mismatch between rhetoric and reality. The rhetoric typically promises much more than the reality of federal research support can possibly deliver. The result is inflated expectations, which may lead to disillusionment with the efficacy of science as a source of technology. The rhetoric also generates opposition by those who do not want to see the federal agencies choosing and conducting R&D programs to develop industrial technology, for we view such activities as anti-competitive, wasteful and, in any case, likely to be a weak contributor to useful industrial capability. As a consequence, the rhetoric makes it difficult to generate a consensus behind useful, non-controversial proposals like the university centers for interdisciplinary generic research, carried on in collaboration with scientists and engineers from industry.

The Stevenson-Wydler Act, plagued with this dichotomy from the beginning, is not the only example. A more dramatic one was the Cooperative Automotive Research Program, initiated by the Carter Administration amid much fan-fare from Congressional supporters who described its objectives as "reinventing the automobile." The implication of the program was that the U.S. auto industry had lagged technologically and that the federal program would restore its competitiveness, thus preserving the auto workers' jobs.

In fact, the program that was envisioned was the support of university-industry research cooperation in useful, basic fields like combustion science, metallurgy, advanced materials and the like. CARP was publicly supported by at least one senior automobile executive, who evidently thought the research would be useful and was expecting some needed regulatory relief in the legislative package. The Reagan Administration cancelled the program as almost its first act upon taking office. Yet the same research activities conducted under different colors might well have been generally accepted as entirely appropriate federal activity. It was, in fact, intended to be a research program of broad applicability, not of commercial technology development.

The Congress, the Administration, the technical community and the industry must all decide to be more realistic about the limits of federal power to sustain the technological performance of the private sector, have more faith in the long term power of research and education to support an effective industrial process for innovation and determine to remove the remaining obstacles imposed by federal policy to the attainment of that performance.

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June 12, 1984

Honorable Doug Walgren
Chairman
Subcommittee on Science,
  Research and Technology
Room 2319
Rayburn House Office Building
Washington, DC . 20515

Dear Doug:

I want to thank you again for the opportunity to testify before your Subcommittee on H.R. 4361. I would like to include for the record the OTA Staff Memorandum entitled "Development and Diffusion of Commercial Technologies: Should the Federal Government Redefine Its Role?" which I mentioned during the course of my testimony.

Additionally, you might be interested in a series of quotes which we excerpted from our hearings on H.R. 4361.

With best personal regards,

Sincerely,

John

JOHN J. LaFALCE
Chairman

Enclosures

JOHN J. LaFALCE, N.Y., CHAIRMAN

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April 9, 1984

The following witnesses testifed before the Subcommittee on H.R. 4361:

Kenneth Wilson, Professor of Physics
Cornell University

George Heaton, Professor of Technology & Policy
Boston University

David Mowery, Professor of Economics
Carnegie-Mellon University

Lewis M. Branscomb, Vice President/Chief Scientist
IBM and
Chairman, National Science Board, National Science Foundation

Myron Tribus, Director
Center for Advanced Engineering Study
M.I.T.

Jordan J. Baruch, President
Jordan J. Baruch Associates

Donald N. Frey, Chief Executive Officer
Bell and Howell Corp.

Russell Drew, President
Viking Instruments Company, representing
The Institute of Electrical and Electronics Engineers

Edwin Mansfield, Professor of Economics
University of Pennsylvania -- submitted testimony

Attached is a list of quotations from those witnesses, and the OTA report, which support the bill on several key issues:

1. The need for technology support.
2. Need for an independent agency/new agency.
3. Stevenson/Wydler report.
4. R&D tax credit/R&D limited partnerships.
5. Federal Industrial Extension Service.

QUOTATIONS OF WITNESSES ON ABOVE KEY ISSUES:

1. NEED FOR TECHNOLOGY SUPPORT

George Heaton: "A technology foundation is needed for two reasons -- (1) it casts the government in a leadership role through the establishment of a new institution with technology as its main focus."

(2) "...the private sector underinvests in R&D because the financial rewards are not sufficiently appropriable by the research performer."

Jordan Baruch: "The United States has a miserable history in the support of technology, a history that must change if we are to maintain our position as an advanced industrial nation."

"This country needs, desperately needs, an Advanced Technology Foundation, and that foundation needs a board to guide it -- a board made up not of scientists but of technologists and representatives...of industry large and small."

Myron Tribus: "In the sale of complex products or high technology products the strength of the dollar has not been important. We lose out because our products are either not as good a design or they have lower reliablity."

We cannot sustain our [economic] position if we invent and they innovate...What we need is a new form of partnership in which the government is involved in a colloborative way with the private sector."

Lewis Branscomb: "Most of the industrial technologies--microelectronics, robotics, supercomputers, bio-engineering, or materials engineering--are most effectively stimulated by federal support of this kind of university centered research, conducted with the participation of private industry."

Looking at the authority in old Section 6 to provide grant money for research on generic technologies, Branscomb said, "I strongly support that as an appropriate action of government."

David Mowery: "The innovative performance of the American economy is critical to growth in income and productivity...I thus endorse the goals of H.R. 4351 without reservation."

"While military and space-related R&D have generated important civilian spillovers, commercial benefits have been less intentional than fortuitous. A less skewed allocation of applied R&D funding could be particularly beneficial to industries that historically have not been major recipients of such funds."

2. INDEPENDENT AGENCY NEEDED/NEW AGENCY

Kenneth Wilson: "I feel that the idea of an ATF, or something like it is urgently needed...I agree that the National Science Foundation cannot carry the burden of technology development. The technology priorities differ substantially for scientific priorities which is the NSF's main concern. And the scale on which we have to address technological isues could destroy the NSF, if the NSF became really seriously involved. And I say this from my practical experience of working with the Supercomputer Panel at the NSF, where the conflicting priorities of technology and science became very evident." Professors Heaton and Mowery agreed with the statement that NSF is not the appropriate vehicle.

Russell Drew: "Unfortunately, I think you are quite correct in assuming that the Department of Commerce on the previous record looks like it is woefully inadequately prepared to do that [pursue its responsibility under Stevenson-Wydler]."

Donald Frey: "I think that the unique thing about this proposal, is its clear delinated flavor toward industrial manufacturing generic research..the constituency for the NSF wants every single dollar to go toward their basic research..which is why I think if you are going to do a job and do it right, you are going to have to develop a new entity with a new constituency."

Jordan Baruch: "One of the nice things about H.R. 4361 is that it is neat, compact, and focussed. It doesn't require the incorporaiton of 3,000-odd people at the National Bureau of Standards or 17 different programs from the National Science Foundation or the Office of Productivity, Technology, and Innovation...Let's keep it clean. Let's make it simple. Let's not overdefine how it is to do its task. Let the board and the staff do that and then let's get out of its way."

"Because these cultures [science and technology] are so different, it would patently be folly to expect a foundation geared to operate within the science culture to be effective in the support of technology."

George Heaton: "New government agencies are typically created to refocus existing activities as much to create newspapers...Today technology development is similarly a matter of new national urgency."

3. STEVENSON-WYDLER REPORT

Russell Drew: "My personal judgment is that implementation is wholly inadequate. They are really looking at things that are already there and existing, and trying to color them a different color, so that it would look like they are in compliance with Stevenson-Wydler."

4. R&D TAX CREDIT/R&D LIMITED PARTNERSHIPS

Jordan Baruch: "It [the R&D limited partnership] may some day be successful. It has not as yet had much impact."

"I also serve as a member of the board and a member of an Investment Advisory Committee. In that role, I review many, many industrial R&D limited partnershp proposals. To date, we have chosen to invest in none of them because our test for investment is not simply that it be a tax shelter but that it have a significant potential for commercial success and contribution."

Joint Committee on Taxation; Report on Etimates of Federal Tax Expenditures--It estimates that the loss of revenue to the Treasury for the incremental R&D tax credit will be $650 million in fiscal yar 1984; $660 million in fiscal year 1985.

Edwin Mansfield: "In all of these nations [U.S., Canada, and Sweden] the increased R&D expenditures due to the tax incentives seem to be substantially less than the revenue lost by the government. The ratio of the tax incentive-induced increase in R&D spending to the foregone government revenue...ranged from about 0.3 to 0.4." This is a 30 cent increase for each $1.00 of lost revenue.

"Based on our findings, it appears that the R&D tax incentives, in their present form, are unlikely to have a major impact in a nation's rate of innovation. One possible way of increasing their effectiveness is to change the computation of the base around...Such a change would not necessarily result in a considerable increase in effectiveness."

5. FEDERAL INDUSTRIAL EXTENSION SERVICE

George Heaton: "An industrial extension experiment deserves to be tried...about half the states today have their own extension programs. At least some of these programs have been highly successful. The potential benefits to be gained for the country in the aggregate are great indeed even if only modest improvements in productivity occur in a large number of firms."

"The federal role should be to fund state programs...and provide them, as necessary, with back up technical assistance."

Myron Tribus: "Consider how this service could address the problems of increased quality and productivity ...In any industrial process the application of [the methods of statistical quality control] can contribute more to quality and productivity than can any other single technology...An extension service could be central in facilitating the application of these methods. It is ridiculous to think that the Government does not have a role to play in this."

Lewis Branscomb: "There is a large area in the diffusion of the results of research out to engineers and others who can use it that needs attention."

David Mowery: "The effectiveness of the agricultural extension program clearly suggests that similar activities could greatly enhance the effectiveenss of a publicly funded industrial research program. However, the analogy is far from straightforward...A vigorous industrial extension program could go some way toward alleviating the costs of transfer and utilization, but such a program would be substantially more ambitious and costly than that currently proposed."

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